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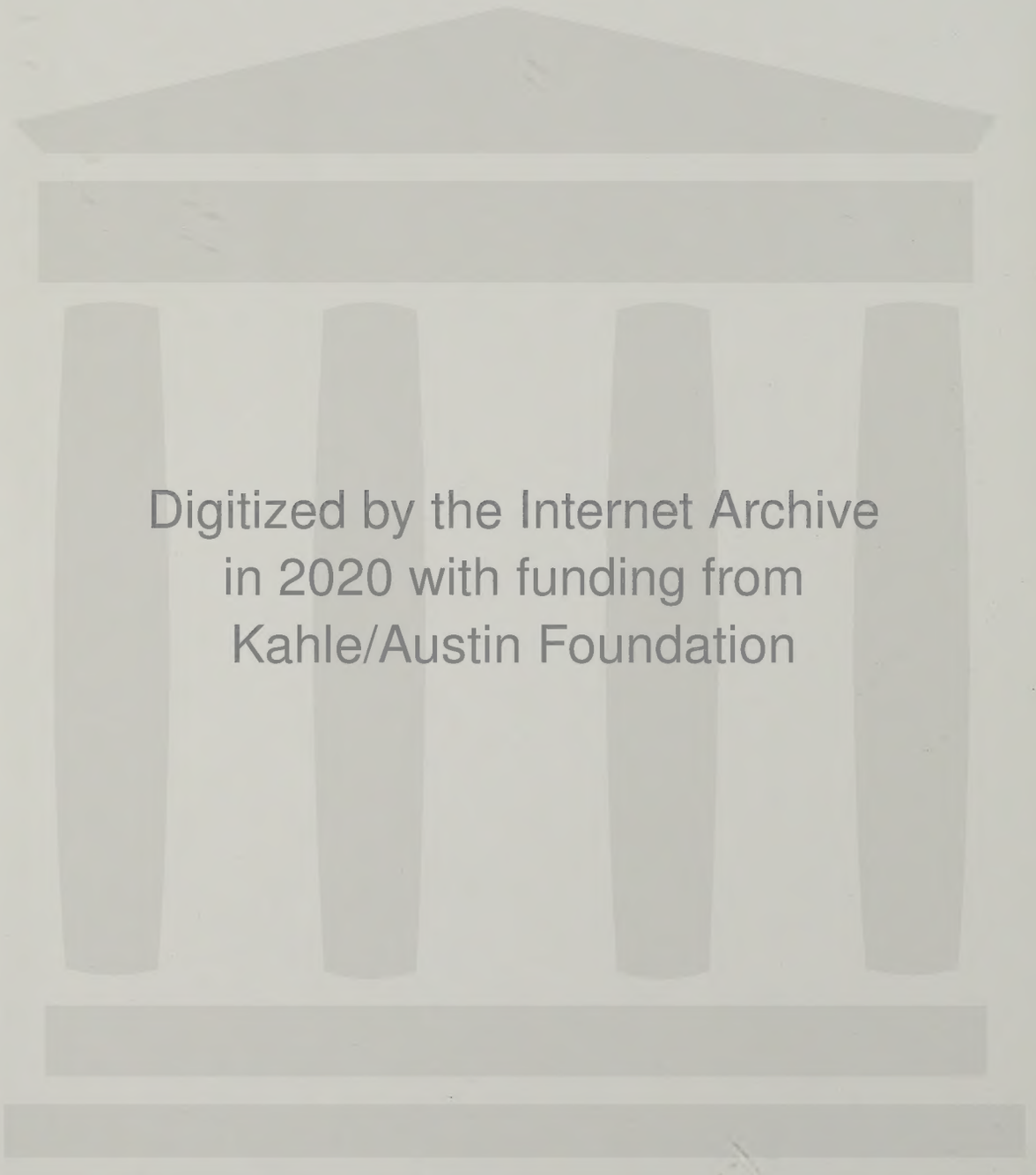
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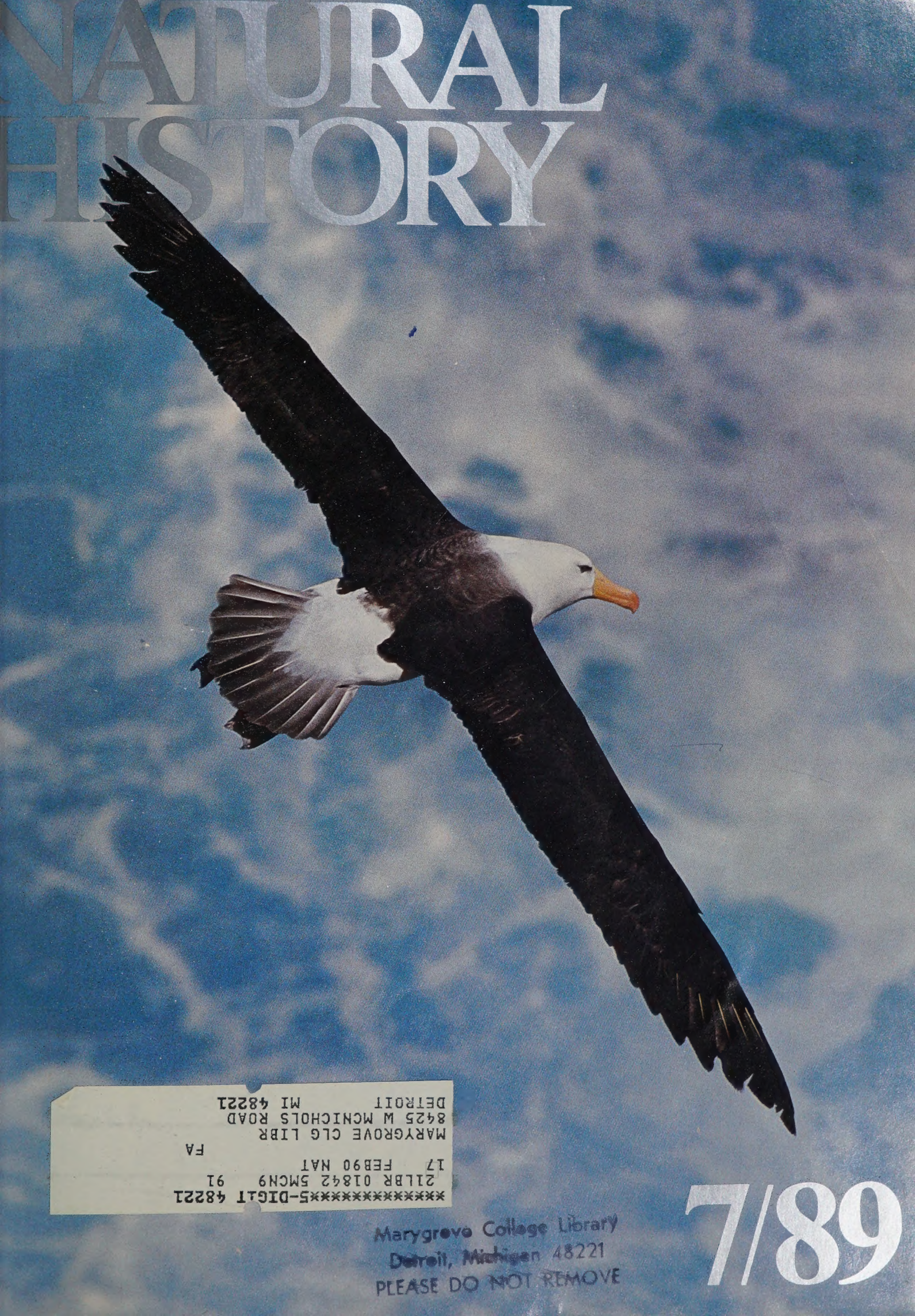

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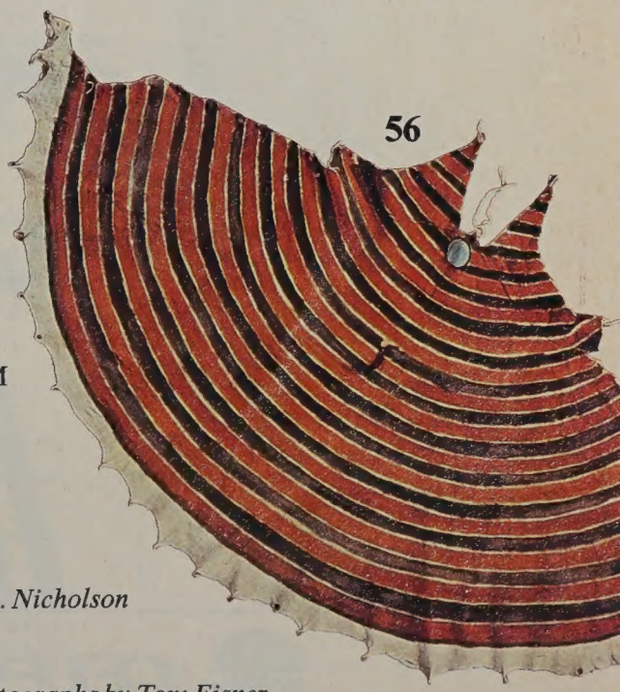

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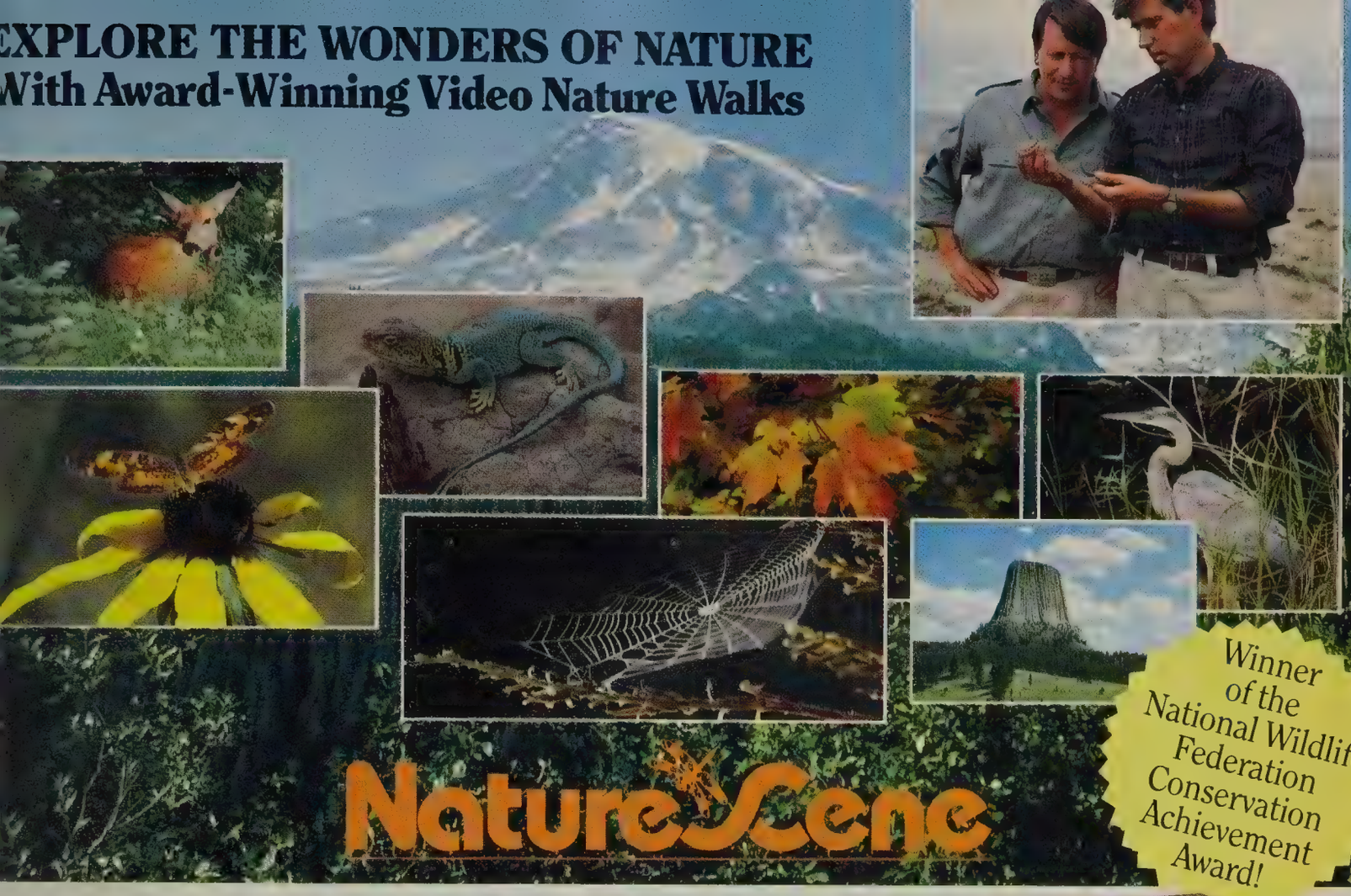

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The Lyme Disease Invasion

Deer have been blamed, but several other mammals also play key roles in the spread of this tick-borne infection

by Thomas J. Daniels and Richard C. Falco

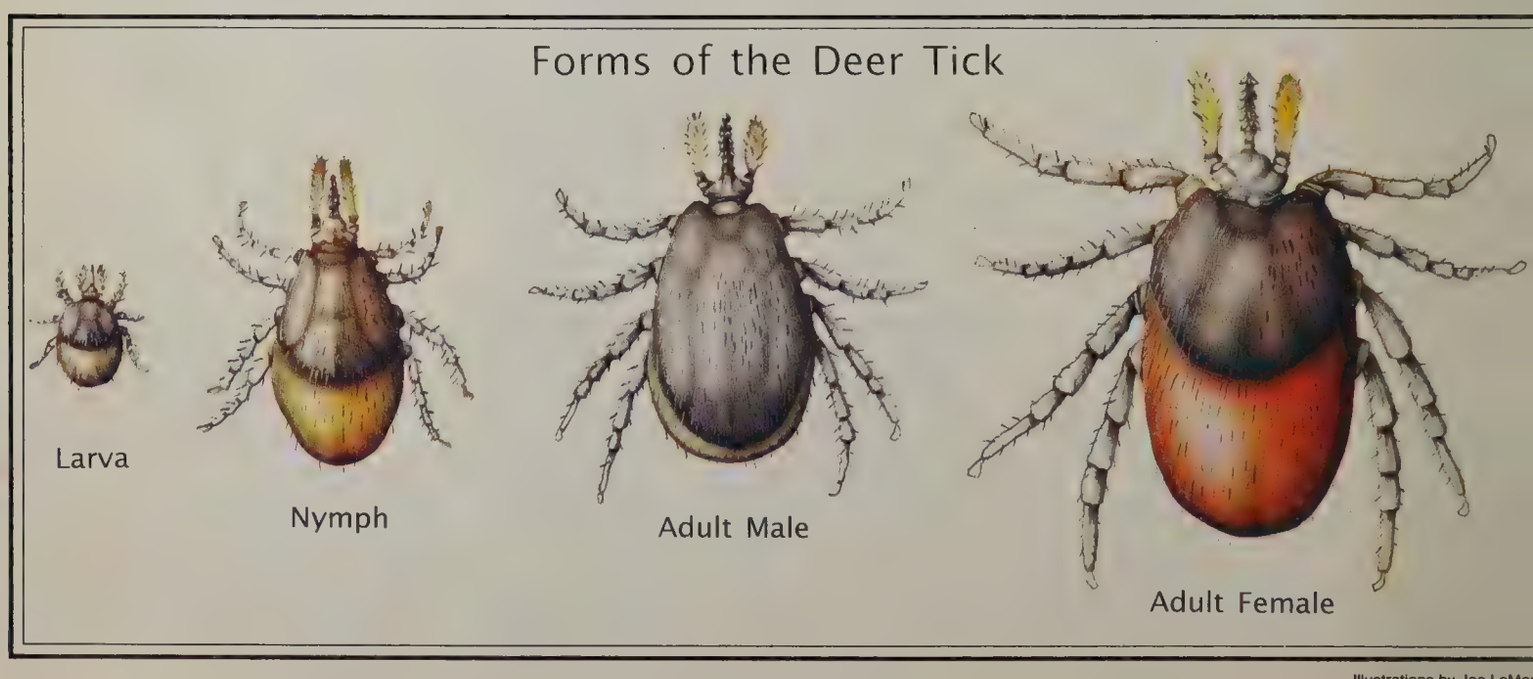
Our herculean precautions had not worked. After four years of nearly daily fieldwork, for which we dressed to the hilt—white coveralls over long pants and long-sleeved shirts, pant legs tucked into boot tops and tightly taped—Rich had contracted Lyme disease. As we stared at the large, circular red rash that had developed on the back of his right thigh, we had to admit it was probably inevitable. Over the years, four of the eighteen fieldworkers who had worked with us at the Medical Entomology Laboratory in Armonk, New York, had become infected.

Yet prevention is all that residents of deer tick country have to rely on. And although early-stage Lyme disease can be relatively mild, the later effects can include heart rhythm abnormalities, neurological problems, and recurring attacks of arthritis. In addition, domestic animals, such as dogs, cats, and horses, also suffer from the malady.

Lyme disease first gained national attention after two mothers from Lyme and Old Lyme, Connecticut, reported to health officials a suspiciously high number of "juvenile rheumatoid arthritis" cases in their neighborhoods. In 1975, in a classic epidemiologic study, Allen Steere, of Yale University, and colleagues discovered that the illnesses were, in fact, another clinical entity, which they called Lyme arthritis. (Since the disease caused much more than inflammation of the joints, its name was later changed to Lyme disease to encompass its broad spectrum of effects.) The cause, isolated from both the ticks and Lyme disease patients, proved to be a spirochete bacterium; the vector, or transmitting organism, was the deer tick, *Ixodes dammini*.

Interestingly, however, the disease was not entirely new to science. In 1909, Arvid Afzelius, a Swedish dermatologist, noted the appearance of a ring-shaped skin rash at the site of a patient's tick bite. Some years later, the rash and its accompanying symptoms gained the official name of erythema chronicum migrans, a reference to its hallmark, a red, persistent, migrat rash. In Europe, the vector was the she tick, *Ixodes ricinus*, which also carr what is now known to be the Lyme dise spirochete, *Borrelia burgdorferi*. Seve other *Ixodes* ticks have since been im cated as vectors; in the United States second species, *I. pacificus*, is known to the vector in the west. The disease m have found its way to the United Sta via infected rodents or domestic anim brought over from Europe on ships or infected ticks hitching long-distance ri on migrating birds.

As of 1988, Lyme disease has been ported in forty-three states. With the ception of AIDS, it is the most importa "new" infectious disease in the country terms of the number of cases and the tential for severe consequences. M cases in the United States are conc trated in three areas: the northeaste coast (primarily New York, New Jers Connecticut, and Massachusetts), the per Midwest (Minnesota and Wisconsi



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and the Pacific Northwest (California and Oregon). The vast majority of cases are reported in the northeast. Westchester County, New York, just north of New York City, where we conduct our field studies, is in contention (along with sites on Long Island, New York, and coastal Massachusetts) for the title of "hottest" Lyme disease area. When Rich discovered he had contracted the disease, though, we had reason to temper our usual excitement about working on an epidemiologic frontier.

The rash meant that he could have been bitten anytime from three days to a month earlier. Because it was summer, when our fieldwork was at its peak, we had little doubt that he had acquired the infected tick locally. Did he recall being bitten? This question was probably asked of every one of the nearly 1,500 or so reported Lyme disease victims in the county in 1988, yet only about 30 percent ever recall such a bite. In Rich's case, too, the answer was no. At the point human beings are most likely to encounter it, a deer tick is about the size of a sesame seed, much smaller than the more familiar dog tick.

Ticks go through four life stages: from eggs to minute larvae to slightly larger nymphs, and finally, to adults. Larvae and nymphs require blood to proceed to the next stage, and adult females need blood to lay their eggs. At each of these stages, the tick seeks an animal host for a single blood meal. Human beings become targets when they are outdoors and lightly clothed. Thus, most Lyme disease cases are reported in mid- to late summer, during and just after the period when nymphal ticks are most active.

But being bitten by a deer tick (whether larva, nymph, or adult) does not necessarily lead to Lyme disease. The tick itself must be infected with spirochetes, a result of having fed previously on an infected host. Approximately one-quarter of the deer tick nymphs in Westchester are infected, having acquired the spirochetes as larvae. Adult ticks are twice as likely to be infected because the adult has had two chances to pick up the spirochete during a blood meal. But adults are active in the cooler weather of spring and fall and are therefore less likely than nymphs to come in contact with humans. In addition, the far less numerous adults are easier to spot and more likely to be removed before spirochetes have been transmitted.

Malaise, nausea, general achiness, fever, and headaches often accompany early Lyme disease, but Rich had none of these. If not for the skin rash, which occurs only about 50 percent of the time, the disease might have gone undiagnosed. Lyme disease—like syphilis, another s rochetal infection—may proceed unc tected for long periods. Weeks to mont after a bite from an infected tick, son one-quarter of untreated patients devel neurological abnormalities, includi meningitis and temporary facial paralys Although less than 10 percent of u treated patients develop cardiac proble such as heart block, with its resultant a rhythmic heartbeat, more than half m develop some form of arthritis months years later. Less commonly, late-sta Lyme disease has been associated wi psychological disorders, multiple-scler sis-like symptoms, and chronic fatigu Early treatment with antibiotics, howev often successfully wipes out the infectio

But because Lyme disease does not no mally confer lasting immunity as a resu of infection, the threat of reinfection r mains. While researchers at the Unive sity of Minnesota and elsewhere are tryi to develop a vaccine, others are explori ways to break the cycle of infection controlling one or more stages of the de tick. Two major stumbling blocks are t difficulty of accurately estimating ho many ticks are out there and an incor plete picture of the deer tick's ecolog Our work, in collaboration with Durla Fish, director of the Medical Entomolo Laboratory, has therefore focused ways of estimating tick numbers and u derstanding the differing life histories local populations.

What we have learned is that the nam "deer tick" is really a misnomer. Mo host–parasite relationships are quite sp cific, the product of a long history of a sault and defense maneuvers as each tri to minimize the unpleasant response the other. Ultimately, host and parasi become attuned to each other and a sort equilibrium or symbiotic relationship d velops. Thus, some lice are found only humans (some specific to certain bod areas), some mites live only on birds, an some ticks live only on lizards or rabbits sheep. A truer deer tick is the so-calle winter tick, which spends virtually its e tire posthatch life, from larva to nymph adult, on a single deer. In contrast, *dammini* is a three-host organism; in eac successive life stage it parasitizes a diffe ent animal. In fact, the immature de tick's catholic taste in potential hosts i sures that virtually all warmblooded wil life in the wooded areas of Westchest County will eventually be infected.

Nonetheless, in their two years of lif deer ticks spend very little time—on about two and a half weeks—on host The rest is a waiting game in an enviro ment where chance seems to play as big

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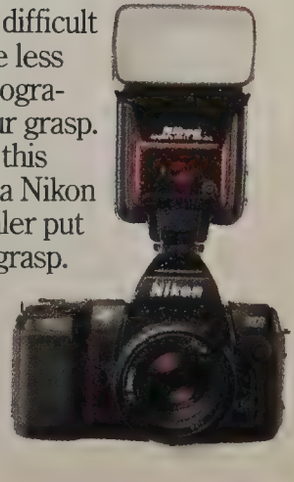

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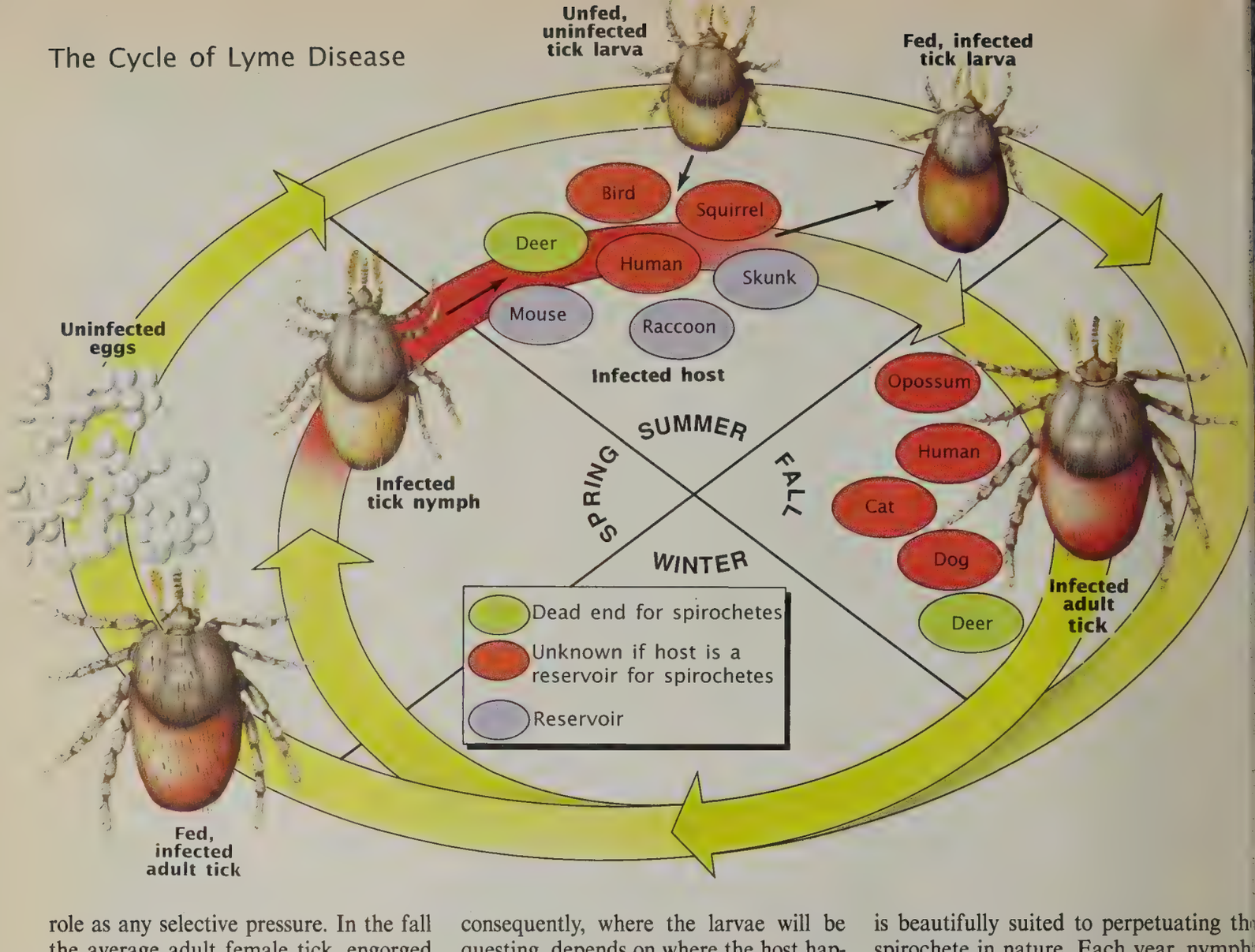

role as any selective pressure. In the fall the average adult female tick, engorged with blood after feeding for about a week, drops from the host, seeks a spot beneath the leaves in the immediate vicinity of her landing point, and enters an extended period of inactivity. As winter fades and temperatures rise, surviving engorged females begin to lay an average of 2,500 eggs in the leaf litter. In addition, unfed adults that successfully overwintered become active in a last-ditch effort to find a host, feed, and reproduce. By the end of spring, what remains of the fed and mated female is a chitinous husk; reproduction truly is the death of her. The eggs will hatch in a month or so, but the larvae—minute, six-legged creatures—are not immediately active. In late summer, thousands of them, each not quite the size of a pinhead, begin their climb up whatever grasses or shrubs are nearby. There they wait for the first unsuspecting host—a mouse, a bird, or a larger animal like a raccoon or deer. After feeding for three to four days, the larvae drop from their hosts and eventually molt. They remain inactive until the following year, when they reappear as nymphs.

Except when hitching a ride on a host, the deer tick moves very little at any stage of life. Where a female lays her eggs and, consequently, where the larvae will be questing, depends on where the host happens to be standing or lying when the tick detaches itself and falls off. If the landing site provides some cover, the female may survive the winter to lay her eggs.

Host finding, too, is a gamble. Larvae and nymphs are relatively indiscriminate, latching on to whatever approximates a host, including the one-square-yard panels of white corduroy we drag along the ground to collect ticks, but ticks are also sensitive to body heat and carbon dioxide in exhaled breath. The host must appear before the waiting tick exhausts its energy reserves. Although ticks are masters at saving energy by remaining inactive for long periods, they are in danger of drying up and must move down vegetation to take up water at ground level before climbing up again to resume questing. For ticks of all sizes, maintaining water balance is a tightrope walk that may decide life or death.

If the larva survives the winter, it will molt into a slightly larger, eight-legged nymph. And if the larva has fed on an animal in which spirochetes thrive, such as the white-footed mouse, it acquires infection and carries the spirochetes into the nymphal stage.

The two-year life cycle of the deer tick is beautifully suited to perpetuating the spirochete in nature. Each year, nymphs of the previous generation emerge and begin infecting hosts before the newly hatched larvae become active. White-footed mice fed upon by the infected nymphs will transmit the infection to the larvae that feed on them later the same summer. (Raccoons and skunks are also competent reservoirs of infection.) Thus the cycle of infection is started anew for another generation of ticks.

Exactly what is the risk of contracting Lyme disease for the average birder, nature lover, or even suburban weekend gardener? Risk of infection is a function of the number of infected ticks in the environment, but this number may well vary with the sampling site and with the sampling technique. Counts of ticks on live mammals can be inaccurate, especially because the very small immature ticks are so easily concealed in the dense fur of their hosts. Drag sampling is more effective and what we have found by using this method in Armonk since 1984 does not augur well. From 1984 to 1986, when Lyme disease was beginning to rise markedly in Westchester, we noted a slight but steady increase in the number of nymphs per square yard sampled. In 1987, however, there was a 29 percent rise from the

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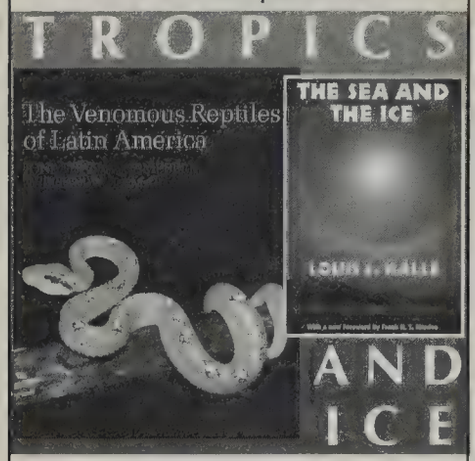

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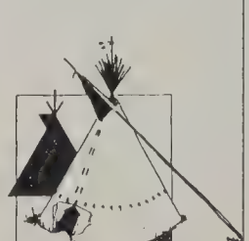

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previous year, and in 1988 we estimated an increase of approximately 40 percent and a population of nearly two nymphs per square yard. Applying an average infection rate of 25 percent, we are left with a staggering one infected tick in every two square yards at our study site.

Although this site is in the heart of the woods, the well-manicured lawns and broad expanses of much-used parkland that characterize Westchester are far from tick free. In one of our studies, we found deer ticks in or near the lawns of ten out of eleven Lyme disease patients. Further examination of one 830-square-yard lawn revealed an estimated 680 adult ticks—almost one tick per square yard—which explains why many victims report being bitten in their own backyards. This phenomenon is directly related to the increasing number of homes nestled in woodland habitat—precisely where deer ticks are so abundant. More time spent in backyards carved from adjacent woods means a greater chance that people will come in contact with ticks.

Another study examined the abundance of ticks in local parks. Deer ticks were the most common tick collected, found in seven of the eight parks studied. In the highest-risk park, we encountered a deer tick every 120 feet traveled. In other words, people spending time outdoors are at risk of encountering infected ticks, and that risk has been increasing.

What happened in the early to mid-1970s that triggered the epidemic we are now weathering? One likely explanation is that the deer population in the northeast has itself increased dramatically in recent years. Areas of New York and surrounding states that were once farmland have, in the last twenty-five to fifty years, been cleared for more profitable ventures. In the intervening years, these cultivated lands have undergone ecological succession, and the ceaseless encroachment of woodland has made more habitat available to remnant deer populations and other woodland animals. This, coupled with the relentless movement of people to the suburbs, has required sharing of the land by man and wildlife. Contact between humans and a plethora of wildlife denizens has become a daily occurrence, and with it has come contact with the burgeoning tick population.

The role white-tailed deer play in the cycle of Lyme disease has been exaggerated considerably. This is not difficult to understand. After all, the tick's name certainly suggests some logical link between the presence of deer and incidence of the disease, but this link is an indirect one. Deer are very good hosts for adult ticks; both males and females climb aboard th animals in the fall, after the nymphs an larvae have all but disappeared, and tw very important events take place. The fe males readily attach and begin to imbibe blood meal that will take a week or mor to complete. During this time the male may attach intermittently and feed fo short periods of time, but their primar task is to mate. This they do with ver little difficulty—any number of potentia mates are available for the taking. As female feeds, her hypostome, a wicked looking barbed structure that constitutes primary component of her mouthparts, i buried in host tissue while her genital ap erture is exposed for insemination.

Although mating can take place off host, the likelihood of a male and femal mating on the ground or on vegetation i relatively low. Infected ticks that dro from deer present no risk to humans sinc the ticks are now at the end of their lif cycle and will not feed again. Further more, larvae that result from this feedin will hatch uninfected. Deer are, in es sence, dead-end hosts for the spirochetes Studies conducted by Harvard Universit researchers indicate that deer canno transmit the bacteria to ticks. The Har vard researchers also demonstrated tha virtually all the deer in an area would hav to be eradicated to have an impact on th population of deer ticks. Even if such a eradication project were successful, tick might well parasitize other hosts. Add t this the further complication of continua reseeding of a habitat by ticks brough into an area after hitching rides on bird and mammals.

This leaves us with a perplexing ques tion: Can we control Lyme disease? Pros pects for a vaccine against the spirochet are low for the foreseeable future. Th answer will probably lie in tick-contro measures. So far, these focus on reductio of hosts; treating hosts, specifically mice with insecticides; application of insect cides to the environment; and clearing o tick habitat. All of these need to be stud ied more fully. None have yet proved to b both practical and unequivocally success ful in reducing risk for Lyme disease. Un til some integrated strategy is developed the biggest question for those of us work ing and living in tick country will be, "Wil I get Lyme disease today?"

Thomas J. Daniels is a research assistan professor of medicine at New York Medi cal College. Richard C. Falco is a medi cal entomologist with the Westcheste County Health Department and a visitin scientist with the New York Medical Col lege Medical Entomology Laboratory.

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The Chain of Reason vs. the Chain of Thumbs

Why did several eminent eighteenth-century scientists—including Benjamin Franklin—sit around a table playing thumbsies?

by Stephen Jay Gould

The *Weekly World News,* most lurid entry in the dubious genre of shopping mall tabloids, shattered all previous records for implausibility with a recent headline: "Siamese Twins Make Themselves Pregnant." The story recounted the sad tale of a conjoined brother-sister pair from a remote Indian village (such folks never hail from Peoria, where their nonexistence might be confirmed). They knew that their act was immoral, but after years of hoping in vain for ordinary partners, and in the depths of loneliness and frustration, they finally succumbed to an ever-present temptation. The story is heart-rending, but faces one major obstacle to belief: all Siamese twins are monozygotic, formed from a single fertilized egg that failed to split completely in the act of twinning. Thus, Siamese twins are either both male or both female.

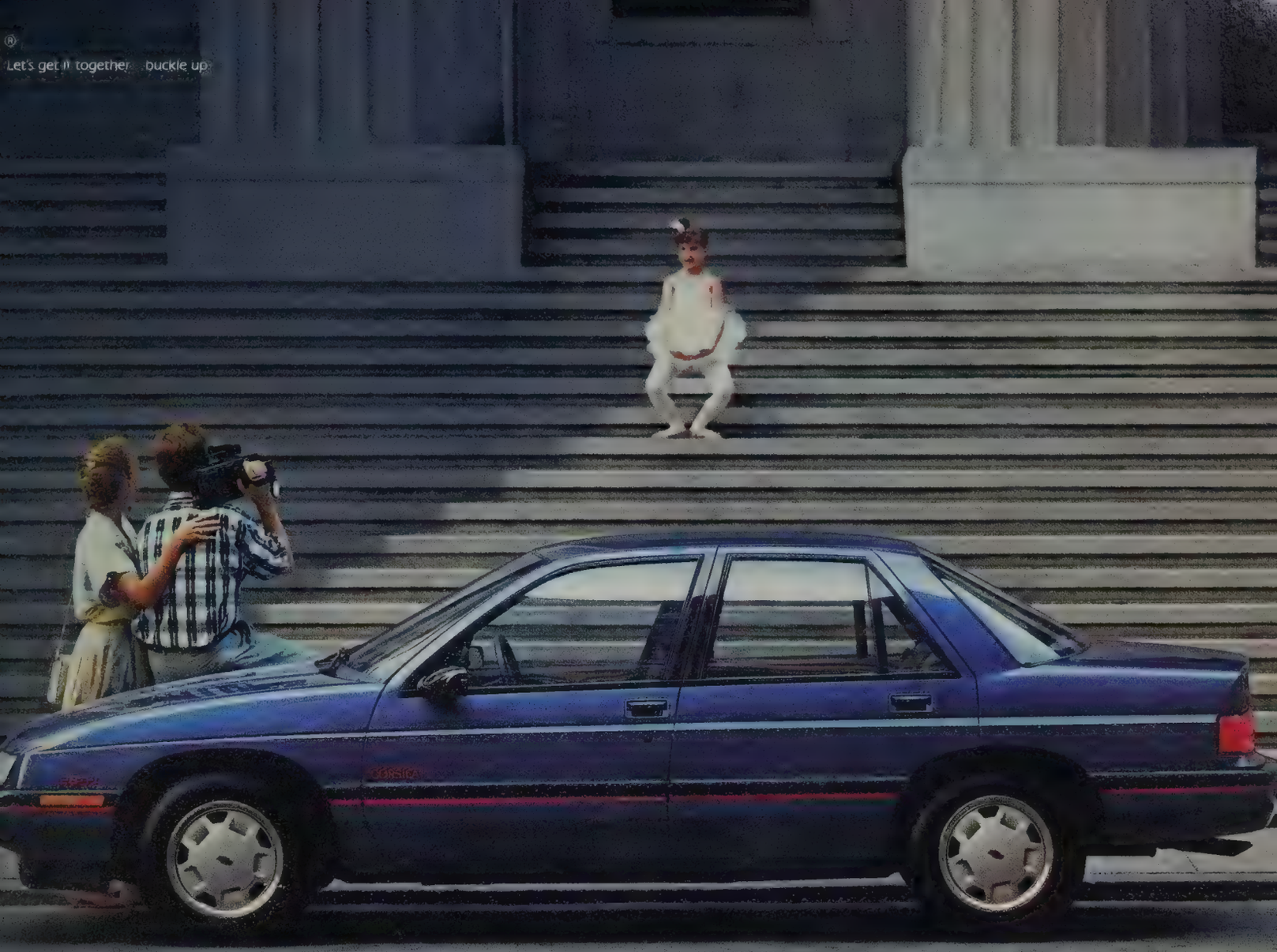
I will, however, praise the good people at *Weekly World News* for one slight scruple. They did realize that they had created a problem with this ludicrous tale, and they did not shrink from the difficulty. The story acknowledged that, indeed, Siamese twins generally share the same sex, but held that this Indian pair had been formed, uniquely and differently, from two eggs that had fused! Usually, however, *Weekly World News* doesn't even bother with minimal cover-ups. Last fall, as I mentioned in my column of March 1989, they ran a screaming headline about a monster from Mars, recently sighted in a telescope and now on its way to earth. The accompanying photo of the monster showed a perfectly ordinary chambered nautilus (an odd-looking and unfamiliar creature to be sure). I mean, they didn't even bother to retouch the photo or to hide in any way their absurd transmogrification of a marine mollusk into an extraterrestrial marauder!

The sad moral of this tale lies, not with the practices of *Weekly World News,* but with the nature of a readership that permits such a publication to prosper—for if *Weekly World News* could not rely, with complete confidence, on the ignorance of its consumers, the paper would be exposed and discredited. The Siamese twin story at least showed a modicum of respect for the credulity of readers; the tale of the Martian monster records utter contempt both for the consuming public and for truth in general.

We like to cite an old motto of our culture on the factual and ethical value of veracity: "And ye shall know the truth, and the truth shall make you free" (John 8:32). But ignorance has always prospered, serving the purposes of demagogues and profitmongers. An overly optimistic account might try to link our increasing factual knowledge of the world with the suppression of cruelties and abuses ranging from execution for witchcraft to human sacrifice for propitiating deities. But this hope cannot be sustained, for no century has exceeded our own in quantity of imposed cruelty (as "improvements" in the technology of genocide and warfare more than balance any overall gains in sensibility). Moreover, despite a great spread in the availability of education, the favored irrationalisms of the ages show no signs of abatement. Presidential calendars are still set by astrologers, while charlatans do a brisk business in necklaces made of colored glass masquerading as crystals that supposedly bathe believers in a salutary and intangible "energy." An astounding percentage of "educated" Americans think that the earth might be less than 10,000 years old, even while the own kids delight in dinosaurs at the loca museum.

The champions of beleaguered rationa ism—all heroes in my book—have bee uncovering charlatans throughout th ages: from Elijah denouncing the prophe of Baal to Houdini exposing the tricks mediums to James Randi on the trail modern hoaxers and hucksters. Obv ously, we have not won the war, but w have developed effective battle strat gies—and would have triumphed long ag were our foe not able, like the Lernea Hydra, to grow several new heads ever time we lop one off. Still, tales of pa victories—including the story of this e say—are not only useful as spurs of en couragement; they also teach us effectiv strategies. For reason is timeless, and i application to unfamiliar contexts can b particularly instructive.

How many of us realize that we ar invoking a verbal remnant of "the greates vogue of the 1780s" (according to histo rian Robert Darnton) when we claim to b "mesmerized" by a wonderful concert or beautiful sunset? Franz Anton Mesme was a German physician who had ac quired wealth through marriage to a wel endowed widow; connections by assiduou cultivation (Mozart, a valued friend, ha staged the first performance of his comi opera *Bastien und Bastienne* at Mesmer private theater); and renown with a b zarre, if fascinating, theory of "anima magnetism" and its role in human health In 1778, Mesmer transferred to Pari then the most "open" and vibrant capita of Europe, a city embracing the odd mix ture so often spawned by liberty: intelle tual ferment of the highest order com bined with quackery at its most abjec



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Voltaire among the fortune tellers; Benjamin Franklin and the astrologers; Antoine Lavoisier amidst the spiritualists.

Mesmer, insofar as one can find coherence in his ideas at all, claimed that a single (and subtle) fluid pervaded the universe, uniting and connecting all bodies. We give different names to this fluid according to its various manifestations: gravity when we consider planets in their courses; electricity when we contemplate a thunderstorm; magnetism when we navigate by compass. The fluid also flows through organisms and may be called animal magnetism. Disease results from a blockage of this flow, and cure of disease requires a reestablishment of the flux and a restoration of equilibrium. (Mesmer himself never went so far as to ascribe all bodily ills to blocked magnetism, but several of his disciples held this extreme view, and such a motto came to characterize the mesmeric movement: "There is only one illness and one healing.")

Cure of illness requires the aid of an "adept," a person with unusually strong magnetism who can locate the "poles" of magnetic flow on the exterior of a human body and, by massaging these areas, break the blockage within and reestablish the normal flux. When working one on one, Mesmer would sit directly opposite his patient, establishing the proper contact and flow by holding the sufferer's knees within his own, touching fingers, and staring directly into her face (most patients were women, thus adding another dimension to charges of exploitation). Mesmer, by all accounts, was a most charismatic man—and we need no great psychological sophistication to suspect that he might have produced effects more by the power of suggestion than by the flow of any fluid.

In any case, the effects were dramatic. Within a few minutes of mesmerizing, sensitive patients would fall into the characteristic "crisis" taken by Mesmer as proof of his method. Bodies would begin to shake, arms and legs move violently and involuntarily, teeth chatter loudly. Patients would grimace, groan, babble, scream, faint, and fall unconscious. Several repetitions of these treatments would reestablish magnetic equilibrium and produce cures. Mesmer carried sheaves of testimonials claiming recovery from a variety of complaints. Even his most determined critics did not deny all cures, but held that Mesmer had only relieved certain psychosomatic illnesses by the power of suggestion and had produced no physical effects by means of his putative universal fluid.

Mesmer's popularity required the development of methods for treating large numbers of patients simultaneously (such a procedure didn't hurt profits either), and Mesmer imposed high charges, in two senses, upon his mostly aristocratic crowd. Moreover, as a master of manipulation, Mesmer surely recognized the social value of treatment in groups—both the reinforcing effect of numerous crises and the simple value of conviviality in spreading any vogue as a joint social event and medical cure. Mesmer therefore began to magnetize inanimate objects and to use these charged bodies as instruments of unblocking and cure.

Many contemporary descriptions and drawings of Mesmer's sessions depict the same basic scene. Mesmer placed a large vat, called a *baquet,* in the center of a room. The *baquet* was filled with "magnetized" water and, sometimes, a layer of iron filings as well. Some twenty thin metal rods protruded from the *baquet*. A patient would grab hold of a rod and apply it to the mesmeric poles of his body. To treat more than twenty, Mesmer would loop a rope from those who surrounded the *baquet* (and held the iron rods) to others in the room—while taking care that the rop contained no knots, for such constriction would impede the flux. Patients woul then form a "mesmeric chain" by holdin a neighbor's left thumb between their ow right thumb and forefinger, while extend ing their own left thumb to the next pa tient down the line. By squeezing a neigh bor's left thumb, magnetic impulses coul be sent all the way down the chain.

Mesmer, whether consciously or no surely exploited both the art and politic of psychosomatic healing. Everything i his curing room was carefully set up t maximize results, efficiency, and profi He installed mirrors to reflect the actio and encourage mass response; he height ened the effect with music played on th ethereal tones of a glass harmonica, th instrument that Benjamin Franklin ha developed; he employed assistants t carry convulsive patients into a "crisi room" lined with mattresses, lest the should hurt themselves in their frenzy. T avoid the charge of profitmongerin among the rich alone, Mesmer provided poor man's cure by magnetizing trees an

An eighteenth-century illustration shows Mesmer performing a cure. Bettmann Archive

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I don't want to commit the worst historical error of wrenching a person from his own time and judging him by modern standards and categories. Thus, Franz Mesmer was not Uri Geller teleported to 1780. For one thing, historical records of Mesmer are scanty, and we do not even know whether he was a simple charlatan, purveying conscious fakery for fame and profit, or a sincere believer, deluded no less than his patients in mistaking the power of suggestion for the physical effects of an actual substance. For another, the lines between science and pseudoscience were not so clearly drawn in Mesmer's time. A strong group of rationalists were laboring to free science from speculation, system building, and untestable claims about universal harmonies. But their campaign also demonstrates that all-embracing and speculative systems were still viewed by many as legitimate parts of science in the eighteenth century. Robert Darnton, who has written the best modern book on mesmerism, describes the French intellectual world of the 1780s (*Mesmerism and the End of the Enlightenment in France,* Harvard University Press, 1968, pages 42–44):

> They looked out on a world so different from our own that we can hardly perceive it; for our view is blocked by our own cosmologies assimilated, knowingly or not, from the scientists and philosophers of the 19th and 20th centuries. In the 18th century, the view of literate Frenchmen opened upon a splendid, baroque universe, where their gaze rode on waves of invisible fluid into realms of infinite speculation.

Still, whatever the differing boundaries and cultural assumptions, the fact remains that Mesmer based his system on specific claims about fluids, their modes of flow, and their role in causing and curing human disease—claims subject to test by the ordinary procedures of experimental science. The logic of argument has a universality that transcends culture, and late eighteenth century debunking differs in no substantial way from modern efforts. Indeed, I write this essay because the most celebrated analysis of mesmerism, the report of the Royal Commission of 1784, is a masterpiece of the genre, an enduring testimony to the power and beauty of reason.

Mesmerism became such a craze in the 1780s that many institutions began to worry and retaliate. Conventional medicine, which offered so little in the way of effective treatment, was running scared. Empirical and experimental scientists viewed Mesmer as a throwback to the worst excesses of speculation. People in power feared the irrationalism, the potential for sexual license, the possibility of rupturing the boundaries of social class that Mesmer's mass sessions could inspire. Moreover, Mesmer had many powerful friends in high circles, and his disturbing ideas might spread by export. (Mesmer counted Lafayette among his most ardent disciples. King Louis XVI asked Lafayette before he departed for America in 1784: "What will Washington think when he learns that you have become Mesmer's chief journeyman apothecary?" Lafayette did proselytize for Mesmer on our shores, although Thomas Jefferson actively opposed him. Lafayette even visited a group of Shakers, thinking that they had discovered a form of mesmerism in their religious dances.)

The mesmeric vogue became sufficiently serious that Louis XVI was persuaded to establish a Royal Commission in 1784 to evaluate the claims of animal magnetism. The commission was surely stacked against Mesmer, but it proceeded with scrupulous fairness and thoroughness. Never in history has such an extraordinary and luminous group been gathered together in the service of rational inquiry by the methods of experimental science. For this reason alone, the *Rapport des commissaires chargés par le roi de l'examen du magnétisme animal* (Report of the Commissioners Charged by the King to Examine Animal Magnetism) is a key document in the history of human reason. It should be rescued from its current obscurity, translated into all languages, and reprinted by organizations dedicated to the unmasking of quackery and the defense of rational thought.

The commissioners included several of France's leading physicians and scientists, but two names stand out: Benjamin Franklin and Antoine Lavoisier. (Franklin served as titular head of the commission, signed the report first, and designed and performed several of the experiments; Lavoisier was the commission's guiding spirit and probably wrote the final report.) The conjunction may strike some readers as odd, but no two men could have been more appropriate or more available. Franklin lived in Paris, as official representative of our newborn nation, from 1776 to 1785. American intellectuals sometimes underestimate Franklin's status, assuming perhaps that we revere him *faute de mieux* and for parochial reasons—and that he was really a pipsqueak and amateur among the big boys of Europe. No such thing. Franklin was a universally respected scholar and a great, world-class scientist in an age when nearly all practitioners were technically amateurs. As the world's leading expert on electricity—a supposed manifestation of Mesmer's universal fluid—Franklin was an obvious choice for the commission. His interest also extended to smaller details, in particular to Mesmer's use of the glass harmonica (Franklin's own invention) as an auxiliary in the precipitation of crises. As for Lavoisier, he was one of the half-dozen greatest scientific geniuses of all time: he wrote with chilling clarity, and he thought with commanding rigor. If the membership contains any odd or ironic conjunction, I would point rather to the inclusion of Dr. Guillotin among the physicians—for Lavoisier would die, ten years later, under the knife that bore the good doctor's name.

The experimental method is often oversold or promulgated as the canonical, or even the only, mode of science. As a natural historian, I have devoted many columns in this series to the different approaches used in explaining unique and complex historical events—aspects of the world that cannot be simulated in laboratories or predicted from laws of nature. Moreover, the experimental method is fundamentally conservative, not innovative—a set of procedures for evaluating and testing ideas that originate in other ways. Yet, despite these caveats about nonexclusivity and limited range, the experimental method is a tool of unparalleled power in its appropriate (and large) domain.

Lavoisier, Franklin, and colleagues conclusively debunked Mesmer by applying the tools of their experimental craft, tried and true: standardization of complex situations to delineate possible causal factors, repetition of experiments with control and variation, and separation and independent testing of proposed causes. The mesmerists never recovered, and their leader and namesake soon high-tailed it out of Paris for good, although he continued to live in adequate luxury, if with reduced fame and prestige, until 1815. Just a year after the commission's report, Thomas Jefferson, replacing Franklin as American representative in Paris, noted in his journal "animal magnetism dead, ridiculed." (Jefferson was overly optimistic, for irrationalism born of hope never dies; still, the report of Franklin and Lavoisier was probably the key incident that turned the tide of opinion—a subtle fluid far more palpable and powerful than animal magnetism—against Mesmer.)

The commissioners began with a basic proposition to guide their testing: "Animal magnetism might well exist without being useful, but it cannot be useful if it doesn't exist." Yet, any attempt to affirm the exis-

ence of animal magnetism faced an in-ense and immediate frustration: the mes-nerists insisted that their subtle fluid had no tangible or measurable attributes. Imagine the chagrin of a group of eminent physical scientists trying to test the exis-ence of a fluid without physical proper-ies! They wrote, with the barely con-ealed contempt that makes Lavoisier's eport a masterpiece of rhetoric, as well as an exemplar of experimental method (the wo are not inconsistent because fair and crupulous procedures do not demand neutrality, but only strict adherence to the ules of the craft):

t didn't take the Commissioners long to ecognize that this fluid escapes all sensa-ion. It is not at all luminous and visible like lectricity [the reference, of course, is to ightning before the days of "invisible" flow hrough modern wires]. Its action is not learly evident, as the attraction of a mag-et. It has no taste, no odor. It works with-ut sound, and surrounds or penetrates you vithout warning you of its presence. If it xists in us and around us, it does so in an bsolutely insensible manner. [All quota-ions from the commissioners' report are ny translations from an original copy in Harvard's Houghton Library.]

The commissioners therefore recog-ized that they would have to test for the xistence of animal magnetism through its ffects, not its physical properties. This rocedure suggested either a focus on ures or on the immediate (and dramatic) rises supposedly provoked by the flow of agnetism during Mesmer's sessions. The ommissioners rejected a test of cures for ree obvious and excellent reasons: cures ke too long and time was awasting as the esmeric craze spread; cures can be aused by many factors, and the supposed ffects of magnetism could not be sepa-ted from other reasons for recovery; na-re, left to her own devices, relieves many ls without any human intervention. Franklin wryly suspected that an unin-nded boost to nature lay at the root of Mesmer's successes. His fluid didn't exist, nd his sessions produced no physical ef-ct. But patients in his care stayed away om conventional physicians and there-re didn't take the ordinary pills and po-ons that undoubtedly did more harm an good and impeded natural recovery.) Mesmer, on the other hand, wanted to cus upon cures, and he refused to co-erate with the commission when they ould not take his advice. The commis-on therefore worked in close collabora-on with Mesmer's chief disciple, Charles eslon, who attended the tests and at-mpted to magnetize objects and people. eslon's cooperation indicates that the ief mesmerists were not frauds, but mis-

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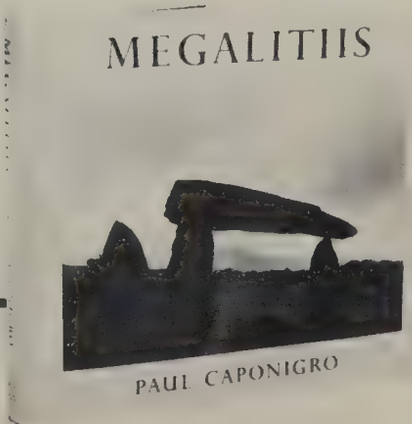

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guided believers in their own system. Mesmer tried to dissociate himself from the commission's findings, arguing that Deslon was a blunderer unable to control the magnetic flux—but all to no avail, and the entire movement suffered from the exposé.)

The commissioners began by trying to magnetize themselves. Once a week, and then for three days in a row (to test a claim that such concentrated time boosted the efficiency of magnetism), they sat for two and a half hours around Deslon's *baquet* in his Paris curing room, faithfully following all the mesmeric rituals. Nobody felt a thing beyond boredom and discomfort. (I am, somehow, greatly taken by the image of these enormously talented and intensely skeptical men sitting around a *baquet,* presumably under their perukes, joined by a rope, each holding an iron rod, and "making from time to time," to quote Lavoisier, "the chain of thumbs." I can picture the scene, as Lavoisier says—OK boys, ready? One, two, squeeze those thumbs now.)

The commissioners recognized that their own failure scarcely settled the issue, for none was seriously ill (despite Franklin's gout), and Mesmer's technique might only work on sick people with magnetic blockages. Moreover, they acknowledged that their own skepticism might be impeding a receptive state of mind. They therefore tested seven "common" people with assorted complaints and then, in a procedure tied to the social assumptions of the *ancien régime,* seven sufferers from the upper classes, reasoning that people of higher status would be less subject, by their refinement and general superiority, to the power of suggestion. The results supported power of suggestion as the cause of crises, rather than physical effects of a fluid. Only five of fourteen subjects noted any results, and only three—all from the lower classes—experienced anything severe enough to label as a crisis. "Those who belong to a more elevated class, endowed with more light, and more capable of recognizing their sensations, experienced nothing." Interestingly, two commoners who felt nothing—a child and a young retarded woman—might be judged less subject to the power of suggestion, but not less able to experience the flow of a fluid, if it existed.

These preliminaries brought the commissioners to the crux of their experiments. They had proceeded by progressive elimination and concentration on a key remaining issue. They had hoped to test for physical evidence of the fluid itself, but could not and chose instead to concentrate on its supposed effects. They had decided that immediate reaction rather than long-term cures must form the focus of experiments. They had tried the standard techniques on themselves, without result. They had given mesmerists the benefit of all doubt by using the same methods on people with illnesses and inclined to accept the mesmeric system—still without positive results. The investigation now came down to a single question, admirably suited for experimental resolution: the undoubted crises that mesmerists could induce might be caused by one of two factors (or perhaps both)—the psychological power of suggestion or the physical action of a fluid.

The experimental method demands that the two possible causes be separated in controlled situations. People must be subjected to the power of suggestion but not magnetized, and then magnetized but not subject to suggestion. These separations demanded a bit of honorable duplicity from the commissioners—for they needed to tell people that nonmagnetized objects were really full of mesmeric fluid (suggestion without physical cause), and then magnetize people without letting them know (physical cause without suggestion).

In a clever series of experiments, designed mainly by Lavoisier and carried out at Franklin's home in Passy, the commissioners made the necessary separations and achieved a result as clear as any in the history of debunking: crises are caused by suggestion; not a shred of evidence exists for any fluid, and animal magnetism, as a physical force, must be firmly rejected.

For the separation of suggestion from magnetism, Franklin asked Deslon to magnetize one of five trees in his garden. A young man, certified by Deslon as particularly sensitive to magnetism, was led to embrace each tree in turn, but not told about the smoking gun. He reported increasing strength of magnetization in each successive tree and finally fell unconscious in a classic mesmeric crisis before the fourth tree. Only the fifth, however, had been magnetized by Deslon! Mesmerists rejected the result, arguing that all trees have some natural magnetization anyway, and that Deslon's presence in the garden might have enhanced the effect. But Lavoisier replied scornfully:

> But then, a person sensitive to magnetization would not be able to chance a walk in a garden without the risk of suffering convulsions, and such an assertion is therefore denied by ordinary, everyday experience.

Nevertheless, the commissioners persisted with several other experiments, all leading to the same conclusion—that sug

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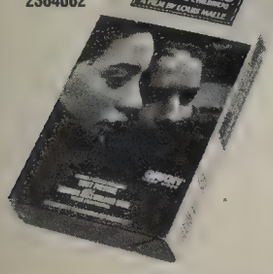

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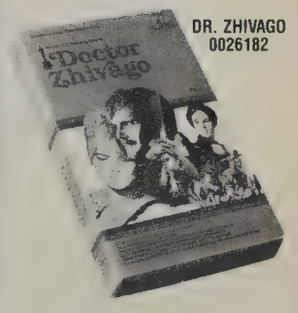

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gestion without magnetism could easily produce full-scale mesmeric crises. They blindfolded a woman and told her that Deslon was in the room, filling her with magnetism. He was nowhere near, but the woman had a classic crisis. They then tested the patient without a blindfold, telling her that Deslon was in the next room directing the fluid at her. He was not, but she had a crisis. In both cases, the woman was not magnetized or even touched, but her crises were intense.

Lavoisier conducted another experiment at his home in the Arsenal (where he worked as Commissioner of Gunpowder, having helped America's revolution with materiel, as much as Lafayette had aided with men). Several porcelain cups were filled with water, one supposedly strongly magnetized. A particularly sensitive woman who, in anticipation, had already experienced a crisis in Lavoisier's antechamber, received each cup in turn. She began to quiver after touching the second cup and fell into a full crisis upon receiving the fourth. When she recovered and asked for a cup of water, the foxy Lavoisier finally passed her the magnetized liquid. This time, she not only held, but actually imbibed, although "she drank tranquilly and said that she felt relieved."

The commissioners then proceeded to the reverse test of magnetizing without unleashing the power of suggestion. They removed the door between two rooms at Franklin's home and replaced it with a paper partition (offering no bar at all, according to Deslon, to the flow of mesmeric fluid). They induced a young seamstress, a woman with particularly acute sensitivity to magnetism, to sit next to the partition. From the other side, but unknown to the seamstress, an adept magnetizer tried for half an hour to fill her with fluid and induce a crisis, but "during all this time, Miss B . . . made gay conversation; asked about her health, she freely answered that she felt very well." Yet, when the magnetizer entered the room, and his presence became known (while acting from an equal or greater distance), the seamstress began to convulse after three minutes and fell into a full crisis in twelve minutes.

The evident finding, after so many conclusive experiments—that no evidence exists for Mesmer's fluid and that all noted effects may be attributed to the power of imagination—seems almost anticlimactic, and the commissioners offered their result with clarity and brevity: "The practice of magnetization is the art of increasing the imagination by degrees." Lavoisier then ended the report with a brilliant analysis of the reasons for such frequent vogues of irrationalism throughout human history. He cited two major causes, or predisposing factors of the human mind and heart. First, our brains just don't seem to be well equipped for reasoning by probability. Fads find their most fertile ground in subjects, like the curing of disease, that require a separation of many potential causes and an assessment of probability in judging the value of a result:

The art of concluding from experience and observation consists in evaluating probabilities, in estimating if they are high or numerous enough to constitute proof. This type of calculation is more complicated and more difficult than one might think. It demands a great sagacity generally above the power of common people. The success of charlatans, sorcerers and alchemists—and all those who abuse public credulity—is founded on errors in this type of calculation.

I would alter only Lavoisier's patrician assumption that ordinary folks cannot master this mode of reasoning—and write instead that most people surely can but, thanks to poor education and lack of encouragement from general culture, do not. The end result is the same—riches for Las Vegas and disappointment for Pete Rose.

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ut at least the modern view does not ondemn us to a permanent and inevitable atus as saps, dupes, and dunces.

Second, whatever our powers of abract reasoning, we are also prisoners of ur hopes. So long as life remains disapointing and cruel for so many people, we all be prey to irrationalisms that promise relief. Lavoisier regarded his countrymen as more sophisticated than previous uckers of centuries past, but still victims f increasingly sly manipulators. (Nothing as changed today, as the Gellers and von anikens remain one step ahead of their ver-gullible disciples):

his theory [mesmerism] is presented today with the more imposing apparatus [I resume that Lavoisier means both ideas nd contraptions] necessary in our more nlightened century—but it is no less false. Man seizes, abandons, but then commits gain the errors that flatter him.

The ever-present temptress is simple ope in a world of woe: Mesmerism "atracts people by the two hopes that touch hem the most: that of knowing the future nd that of prolonging their days."

Lavoisier then drew an apt parallel beween the communal crises of mesmeric essions and the mass emotionalism so ften exploited by demagogues and conuerors throughout history—"*l'enthousisme du courage*" (enthusiasm of courge) or "*l'unité d'ivresse*" (unity of ntoxication). Generals elicit this behavior y sounding the drums and playing the ugles; promoters by hiring a claque to egin and direct the applause after performances; demagogues by manipulating the nob.

Lavoisier's social theory offered no solution to the destructive force of irrationalsm beyond a firm and continuing hegemny of the educated élite. (As my one riticism of the commissioners' report, Laoisier and colleagues could see absolutely othing salutary, in any conceivable form, n the strong emotionalism of a mesmeric risis. They did not doubt the power of the syche to cure, but as sons of the Enlightnment, children of the Age of Reason, ney proclaimed that only a state of calm nd cheerfulness could convey any emoonal benefit to the afflicted. In this reriction, they missed an important theme f human complexity and failed to grasp ne potential healing effect of many pheomena that call upon the wilder emoons—from speaking in tongues to caarsis in theatrical performance to spects of Freudian psychoanalysis. In nis sense, some Freudians view Mesmer s a worthy precursor with a key insight nto human nature. I hesitate to confer ich status upon a man who attained great wealth from something close to quackery—but I see the point.)

I envision no easy solution either, but I adopt a less pessimistic attitude than Lavoisier. Human nature is flexible enough to avert the baleful effects of intoxicated unity, and history shows that revolutionary enthusiasm need not devolve into hatred and mass murder. Consider Franklin and Lavoisier one last time. Our revolution remained in the rational hands of numerous Franklins, Jeffersons, and Washingtons; France went from the Declaration of the Rights of Man to the Reign of Terror. (I do recognize the different situations, particularly the greater debt of hatred, based on longer and deeper oppression, necessarily discharged by the new rulers of France. Still, no inevitability attended the excesses fanned by mass emotionalism.) In other words:

Antoine Lavoisier
Lost his head
Benjamin Franklin
Died in bed.

From which, I think, we can only conclude that Mr. Franklin understood a thing or two when he remarked, speaking of his fellow patriots, but extended here to all devotees of reason, that we must either hang together or hang separately.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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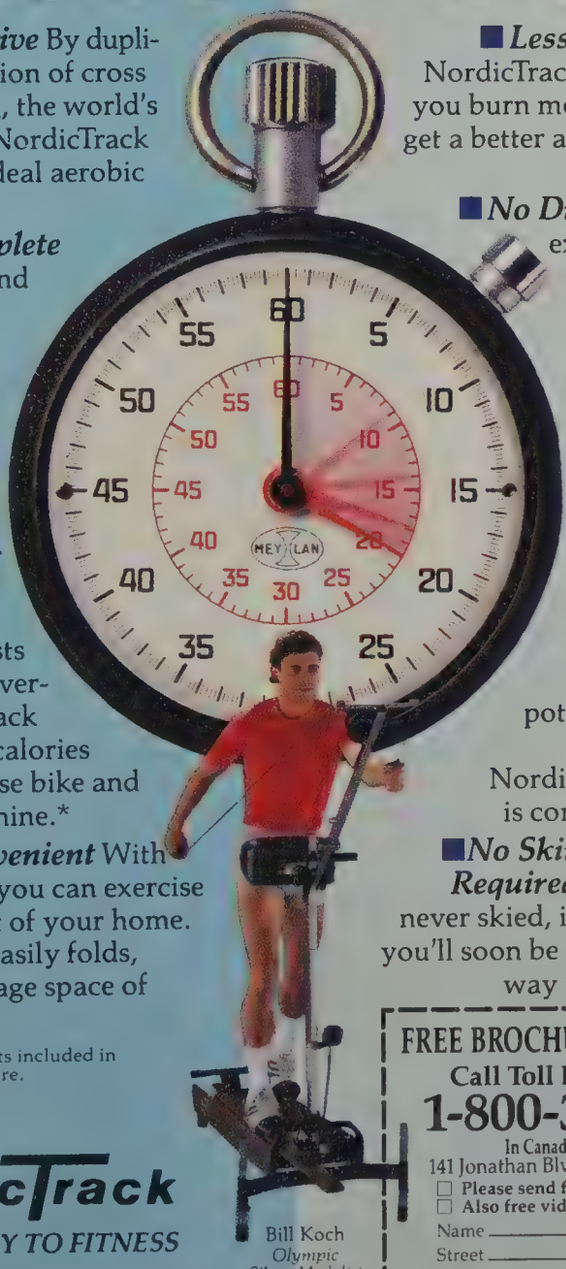

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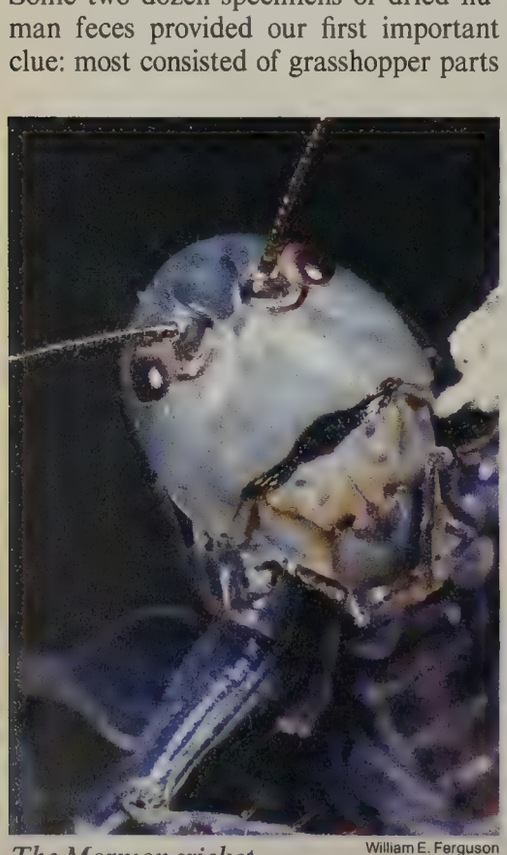
A Grasshopper in Every Pot

In the desert West, small game made big sense

by David B. Madsen

In 1984, I and other archeologists from the Utah State Historical Society were investigating Lakeside Cave, at the western edge of the Great Salt Lake, when we made an unexpected discovery. While digging into deposits left by prehistoric peoples—Great Basin hunter-gatherers visited the cave intermittently during the past 5,000 years—we found tens of thousands of grasshopper fragments. Bits of the insects pervaded every stratum we uncovered, and extrapolating to the entire floor area, we estimated that the cave contained remains from as many as five million hoppers.

At first we had no ready explanation for this phenomenon. Nor could we explain why the cave deposits were so evenly layered with sand from the nearby beach. Some two dozen specimens of dried human feces provided our first important clue: most consisted of grasshopper parts in a heavy matrix of sand. This told us that people ate the hoppers and suggested that the sand was somehow involved in processing them for consumption.



The Mormon cricket William E. Ferguson

Coincidentally, one day in the spring of 1985, some amateur archeologists who had worked with us excitedly reported finding "millions" of grasshoppers lying along the eastern margin of the lake. When we went to investigate, we found that enormous numbers of the insects had flown or been blown into the salt water and had subsequently been washed up, leaving neat rows of salted and sun-dried grasshoppers stretched for miles along the beach. As a result of varying wave action, as many as five separate rows existed in places; they ranged from an inch wide to more than six feet wide and nine inches thick and contained anywhere from 500 to 10,000 grasshoppers per foot. The rows, well sorted by the waves, contained virtually nothing but grasshoppers coated with a thin veneer of sand.

Up until then we had envisioned grasshopper collecting to be a rather tedious task, but we now realized that the prehistoric hunter-gatherers at Lakeside Cave could simply have scooped up grasshoppers piled along the beaches and consumed the sun-dried product directly. The sand in the dung was the residue of sand clinging to the hoppers that were consumed. The sand layers and the innumerable grasshopper fragments in the cave apparently resulted from winnowing the grasshoppers to remove sand, a task probably done prior to hauling much of the harvest elsewhere (far from fresh water, the cave is at best a temporary base).

This evidence that prehistoric hunter-gatherers ate insects prompted us to search the ethnographic and historical record of Native American groups in the western United States to see if similar practices were observed in more recent times. We discovered that insects, particularly grasshoppers and the grasshopperlike Mormon crickets (so named because they had threatened to destroy the Mormon pioneers' first crops in 1848), were indeed favored resources in the Great Basin and Colorado Plateau and were regularly included in the diet. Speaking of the Ute and Southern Paiute, for example, geologist-ethnologist John Wesley Powell noted in the 1870s that

> grasshoppers and crickets form a very important part of the food of these people. Soon after they are fledged and before their wings are sufficiently developed for them to fly, or later in the season when they are chilled with cold, great quantities are collected by sweeping them up with brush brooms, or they are driven into pits, by beating the ground with sticks. When thus collected they are roasted in trays like seeds and ground into meal and eaten as mush or cakes. Another method of preparing them is to roast great quantities of them in pits filled with embers and hot ashes. . . . When these insects are abundant, the season is one of many festivities. When prepared in this way these insects are considered very great delicacies.

Crickets and grasshoppers were commonly collected simply by picking them off bushes and other ground cover or by digging ditches and driving the insects into them. Such methods are relatively labor-intensive operations, however, and whenever possible, native people took advantage of natural traps to increase the collection rate. An 1864 account of cricket collecting along the Sevier River in Utah describes an occasion when a small group quickly gathered "fifty bushels" by driving the insects into the stream with willow branches and scooping them up in carrying baskets.

According to the historical accounts, grasshoppers and crickets were usually roasted and ground, then mixed with pine

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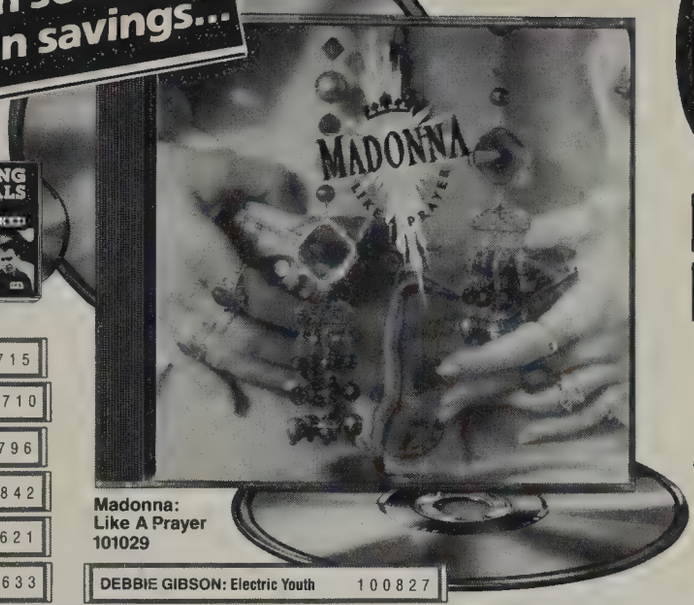

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nuts, grass seeds, or berries to make cakes. The cakes, dried in the sun, could be stored for considerable periods of time. Native Americans also ate the insects whole, as we had discovered at Lakeside Cave, where people apparently consumed the salted and sun-dried grasshoppers much as residents of any present-day neighborhood lounge consume beer nuts.

While the prospect of eating insects is disturbing to Western taste, this bias is essentially cultural, as Vincent Holt noted a century ago in a book entitled *Why Not Eat Insects?* Moreover, hunger can quickly override squeamishness, and numerous historical accounts tell of travelers trading with Native Americans for "desert fruitcake." As Edwin Bryant noted in 1849 after buying up all one Great Basin group had to offer, "The prejudice against the grasshopper 'fruitcake' was strong at first, but it soon wore off, and none of the delicacy was thrown away or lost." Modern American prejudices are just as easily altered. Participants in the Lakeside Cave project, who felt motivated to eat some grasshoppers in the name of science, soon began referring to the food as "desert lobster." (Interestingly, the Goshute of western Utah, after first being exposed to shrimp, called them "sea crickets.")

Nutritionally, dried grasshoppers (our species was *Melanoplus sanguinipes*, or the migratory grasshopper) weigh in at about 60 percent protein, 11 percent carbohydrate, and 2 percent fat. Mormon crickets (*Anabrus simplex*) are similar, but have substantially more fat (about 16 percent). Grasshopper protein hasn't been analyzed yet, but crickets have all the amino acids required in the human diet.

Our archeological and ethnographic documentation of insect eating led us to explore the economics of the practice. Many behavioral scientists theorize that people, like other animals, exploit those food resources that benefit them the most in terms of energy acquired for the effort expended. This is at heart an evolutionary argument: simply put, people who get more for less should be more successful at survival than those who get less for more, and over the long term, their dietary practices are likely to prevail. Scientists have used this "optimal foraging" theory to evaluate existing hunting and gathering peoples around the world, and have concluded that such groups do indeed tend to rely most heavily on those resources that they can collect most efficiently.

We decided to apply this theory by calculating the rate of return of insect collection—the number of calories returned for each unit of time invested—and comparing this with rates for the other resources available to hunter-gatherers in the desert West. Such rates were already known or estimated for a wide variety of wild plants and game. Given our lack of aboriginal collecting and processing skills, we made no pretense of duplicating the exact rates of return possible for prehistoric insect collectors. Our experiments did, however, attempt to provide a basis for relative ranking of insects and other resources.

David B. Madsen

Salted and sun-dried, grasshoppers line the shore of the Great Salt Lake.

Our basic approach was to collect insects under a number of different conditions for set periods of time, process the harvests until they could be eaten or further prepared for consumption, and then weigh and analyze the results to determine the number of calories per pound. First we collected the grasshoppers piled along the Great Salt Lake beaches. Five tests were run on rows of different widths and thicknesses. We found that one person could collect an average of 200 pounds of sun-dried hoppers per hour. We included no processing time since this resource could be consumed directly.

Laboratory analyses of the hoppers indicated a yield of just over 1,365 calories per pound. (For comparison, a pound of cooked medium-fat beef produces about 1,240 calories and a pound of wheat flour about 1,590 calories.) We thus came up with an average return of 273,000 calories per hour of effort invested. Even when we took a tenth of this figure, to be conservative, we found this to be the highest rate of return of any local resource. It is far higher than the 300 to 1,000 calories per hour rate produced by collecting most seeds (such as sunflower seeds and pine nuts) and higher even than the estimated 25,000 calories per hour for large game such as deer or antelope. Put another way, an hour spent collecting twenty pounds of sun-dried grasshoppers provides the equivalent of about twenty-two pounds of meat.

As the bountiful yield from beach rows may represent an extreme situation, we also tried collecting insects using techniques that we felt would produce minimum rates. These experiments, conducted in 1986 and 1987 north of Dinosaur National Monument, along the Colorado–Utah border, focused on Mormon crickets, which we handpicked during warm morning hours, when they are relatively active—probably the most labor-intensive method. Again we did not include processing time, since the crickets are readily killed while being collected and only a little labor is required in sun-drying the catch.

The crickets, in densities of ten to thirty individuals per square yard, rove in bands, or groups, covering more than a square mile. Three tests involved picking crickets from bushes, grass, and the ground surface and produced 600, 884, and 1,452 crickets per hour, or an average of nearly two and one-third pounds. Two other tests involved crickets picked from vegetation and the water surface along the margin of a small lake, and produced 5,652 and 9,876 per hour, or an average of nearly eighteen and one-half pounds. Crickets readily cross streams or lakes in their paths and often wind up along water margins or in eddies, where they reach densities of several hundred per square yard.

Dried crickets produced about 1,270 calories per pound. The numbers in our tests thus converted to an average of 2,959 calories per hour for handpicking from ground cover and 23,479 calories per hour from along the lake margin. The lower of these two figures surpasses the return rate of all local resources except for small and large game animals, while the higher one compares favorably even with deer or other large game.

Our findings thus showed that the use of insects as a food resource made a great deal of economic sense. This may be hard to appreciate for us nonforagers. Consider, however, the caloric value of some fast-food items commonly available in Utah today: a Wienerschnitzel chili dog has 269 calories, a slice of "supreme" Thick'n Chewy pizza from Pizza Hut has 480 calories, and a McDonald's Big Mac has 541 calories. One person collecting crickets from the water margin for one hour, yielding eighteen and one-half pounds, therefore accomplishes as much as one collecting 87 chili dogs, 49 slices of pizza, or 43 Big Macs. This comparison not only shows that insect collecting is efficient but even makes crickets sound more appetizing.

We cannot estimate the extent to which insects accounted for the diet of the inhabitants of the desert West. For them, as for hunter-gatherers generally, resources were variable and not always predictable, changing in availability from season to season, from year to year, and from place to place within the customary territory. Collectors cope with such variation by harvesting a wide array of plants and animals. But we do know that grasshoppers and crickets were commonly available, more than they are today, with the liberal application of pesticides. Given the high ranking of such resources in terms of efficiency, we may conclude that insects were an important food.

Peter Skene Ogden's 1826 journal account of a Native American group living north of the Great Salt Lake sums up the contrast between European-American prejudices and economic reality:

> One of their dishes, not of small size, was filled with ants. They collected them in the morning early before the thaw commences. The locusts they collect in Summer and store up for their Winter; in eating they give the preference to the former, being oily; the latter not, on this food these poor wretches drag out an existence for nearly four months of the year; they live contented and happy; this is all they require.

David B. Madsen is the state archeologist in the Antiquities Section of Utah's Division of State History, Salt Lake City.

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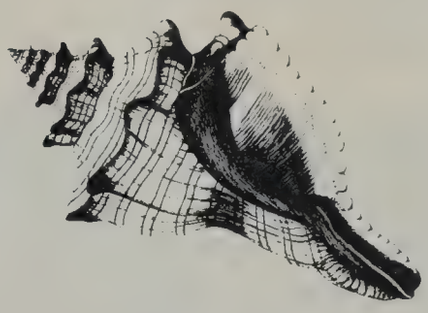

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Black-browed albatrosses and rockhopper penguins share a breeding colony on Beauchene Island in the South Atlantic. Birds refrain from nesting on the central strip, which the albatrosses use as a runway to achieve liftoff on windless days.

Albatross Alley

After eight months of ocean wandering, huge numbers of black-browed albatrosses touch down in the Falklands to breed and feed

Text and photographs by Ian J. Strange

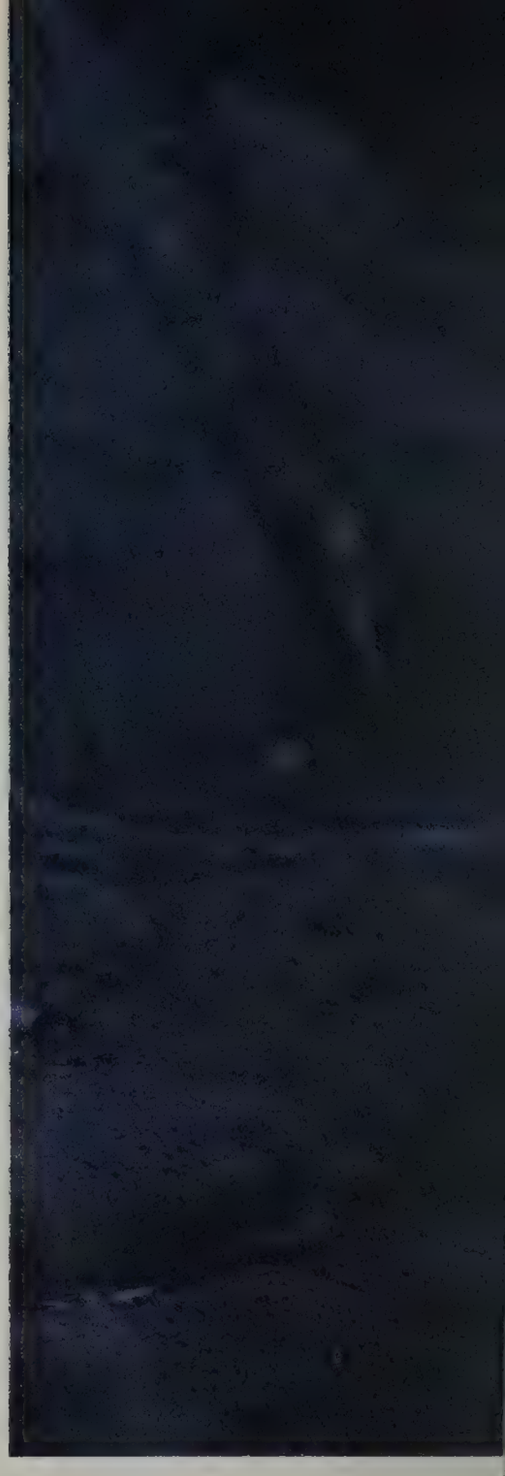
In 1963 I made my first excursion to Beauchene Island, a small "outlier" on the southeast side of the Falkland archipelago in the South Atlantic. The light wind that blew off the island carried the unmistakable odor of a seabird colony, yet I saw few signs of birds. Except for the low murmur of surf, the place was eerily silent. Once ashore and in the cover of the tussock grass, a giant species of *Poa* that flourishes on many Falkland islets, I found that even the pungency of the guano had been absorbed by the dense, nine-foot-high vegetation that covered, or so I first thought, much of the island.

That moment when I first pushed out through the fringe of tussock growth is still vivid in my memory. The vegetation, which had obscured my view of the other side of the island, abruptly ended on the edge of a high bank. Directly below and ahead, stretching out along the island's western shore, was a huge, densely packed colony of at least a million and a half black-browed albatrosses and rockhopper penguins. Suddenly the noise of the surf was transformed into the roar of sound from this avian metropolis. The rich smell of guano again welled up, the ammonia so strong that my eyes burned. This would account for the tussock growth, for in certain conditions, damp, warm air rising off the colony would carry the fumes as a form of nitrogen to the plants.

The black-browed albatross—also called mollymauk, a local term believed to be a corruption of *mollemugge,* the Dutch whalemen's name for the arctic fulmar—is the most common of the nine albatross species of the Southern Hemisphere. Circumpolar in distribution, it breeds on islands near New Zealand, in the Indian Ocean, and in the South Atlantic. Its largest breeding grounds are on the Falkland Islands, situated some 300 miles northeast of Cape Horn, the tip of South America. In 1987, I surveyed breeding populations at twelve sites in the Falklands and estimated that some three-quarters of a million pairs return to these islands each year to breed.

Most of the Falkland black-browed albatross colonies occupy cliff tops or steep slopes, where the birds can lift off their

As a prelude to mating, albatrosses preen each other. Most black-browed albatrosses mate for life and return to the same nest year after year.



nests and ease into flight on updrafts. But this colony, one of the world's largest concentrations of black-brows, covered a gently inclined plateau at a low elevation. I wondered how these birds, particularly those in the center of the aggregation, took flight without first having to trek to the coast to gain lift for takeoff. A species that spends more than half of its life on the wing in seemingly effortless flight, the black-brow is ungainly on land. It walks with difficulty and often has to extend its wings to steady itself. With a wingspan of more than six feet, an albatross moving through a crowded colony, where nests may be just a yard apart, would create a considerable disturbance.

Much of this particular nesting ground, only a few feet above sea level, was covered with broken rock debris overlying a clay base. Thousands of years ago, the area was covered with a deep layer of peat, formed from the tussock. This had slowly eroded through a combination of the birds' nest building and the action of wind and rain. Today, the eroded nesting plateau lies some fifteen to thirty feet below the tussock, and the slight difference in levels between the two, I was to discover, is sufficient to create updrafts. In normal conditions, when predominantly westerly winds sweep the colony, birds scramble up onto mounds of rock debris and lift off into flight. But what happens, I wondered, in calm conditions?

The answer came on a hot day when not a breath of wind stirred. Although every square inch of the colony seemed to be taken up with the huge pedestallike albatross nests or by the rockhoppers nesting on the ground in between, every now and again I would come upon narrow belts of clear ground. One such strip was several yards wide and perhaps 150 feet long. On either side of this space, birds fought over their territories, yet this valuable nesting ground was untouched.

On this day, hundreds of albatrosses lined up at the head of the strip and, as though directed by some invisible controller, took their turn running along the strip and lifting off into the still air. Twenty years later, the area of beaten clay is still clear of nesting birds. On my site maps it is labeled the "Runway" and remains an important reference point, for I am sure it will be there for many years to come.

The 420 islands that make up the Falkland archipelago are perfectly situated to provide for the needs of millions of seabirds. Lying along the shallow-water edge of the Patagonian shelf, the islands are brushed by the Falkland current and act as a "breakwater" to the strong flow. The effect is an upwelling of one of the richest marine faunas in the world. Where the current's flow is greatest, demersal marine species, which normally occur on or near the bottom, are upthrust, and both these and pelagic species found in water columns or close to the surface are readily available to surface feeders such as the black-brows.

Outside the breeding season, the Falklands' population of black-brows are free to disperse widely in pursuit of food. During one program about 11,000 Falkland nestlings were banded, and some of these birds were later recovered from the coast of South Africa and Angola. Many recoveries, however, were from the coast of Brazil, Uruguay, and Argentina, suggesting that many birds follow the Falkland current northward. During the breeding season, black-brows are restricted in their feeding range, especially during the austral summer months of January and February, when their chicks may demand more than a pound and a half of food daily. Catering to the incessant needs of a chick, an adult bird can range only short distances. During this critical time the current's bountiful food supply is indispensable to the albatross population. The choice of colony site is ruled to a degree by wind conditions, availability of nesting material, and perhaps even precipitation, but the overriding factor is easy access to food at chick-rearing time.

In the Falklands, the black-brow's breeding season begins with the return of the male birds to the colonies in the first days of September, the austral spring. The females arrive about a week later. Pairs return annually to breed at the same nests, which they enlarge each season, the characteristic column of mud and vegetation often rising to a height of two feet. Such stately nests may represent many years of breeding by the same pair; although the average life span of the black-browed albatross is not yet known, there are records of individuals living for more than forty years.

On his arrival, the male starts to renovate the nest. He sits on it, stretches his neck out, and scrapes together nearby mud and vegetation. Using his bill as a spatula, he plasters the collected materia to the column. With the female's return nest refurbishing continues as part o courtship, with the female often taking the place of her mate on the nest.

For the first three weeks of its life, th single albatross chick is brooded by it parents. Thereafter, the gray-down-cov ered youngster sits supreme in the shallov cup of the thronelike nest while the adult scavenge the surface of the seas for food While banding nestlings, I had firsthan

xperience of the kinds of food being rought to the young albatrosses. On be- ng approached, the nestling, as a form of efense, faces the intruder and claps its ill. If this warning is not heeded, the bird eliberately vomits its previous meal on he apparent predator.

Squid and some fish, I quickly discov- red, were important components of the iet, but in this particular colony, a far reater proportion of the diet consisted of obster krill, a small crustacean that in the elatively warm subantarctic waters of the alklands takes the role of the Antarctic cean's *Euphausia superba,* the one spe- ies correctly called "krill." Although ee-swimming, lobster krill, carried by urrents, tides, and upwelling, concen- ate in "food fields." A visit to one of ese fields left no doubt in my mind that alkland black-brows form colonies near ch grazing areas.

Enroute to one of the largest breeding concentrations of albatrosses, we navigated through a chain of islands, known as the Jasons, that spanned one of the main western streams of the current. For some thirty miles, the sea boiled as it was squeezed between the islands and forced up over underwater ridges joining the island chain. In these streams of disturbed water, albatrosses and a variety of other seabirds—prions, shearwaters, terns, and storm petrels—continually alighted on the water to take prey, while diving fur seals and penguins added to the feeding spectacle. But even this scene was surpassed when I reached my destination.

From a hillside above the colony, I saw a continuous stream of birds making their way from a colony out to what appeared to be a low-lying reef, perhaps two miles offshore. Through binoculars, I found the reef transformed into a huge raft of feeding albatrosses covering an area some 1,500 feet long and 150 or more wide. The birds exploited this food field for nearly three days before it eventually dispersed or was borne away by currents. Composed of lobster krill, these fields materialize on the doorstep of the colonies at a critical time in the nesting season.

I discovered another example of this fortuitous timing, involving a different food source. A colony to the southeast of the archipelago was situated near an area particularly rich in *Loligo* squid. Little is known of the natural history of this squid, except that it is fast growing and short-lived, going through its entire life cycle within a year. We do know that the species occurs in enormous concentrations on the shelf when albatrosses are breeding.

Many of my observations of black-brows were made at New Island, at the west of the archipelago, where the colo-

A parent transfers regurgitated seafood to its soon-to-fledge young in a typical crossed-bill fashion. After four months of nurturing at the nest, young albatrosses leave the colony to begin a largely airborne existence. After five or six years, they return to their home grounds.

nies have long been known to man. In the late 1700s, New Island, so named by whalers and sealers from New England ports, became an important base for these exploiters, who annually gathered albatross and penguin eggs to replenish their food stocks. The same New Island colony where I conducted much of my research was described in 1797 by Capt. Edmund Fanning, an American sealer. Fanning recorded the date of black-brow egg laying as October 10. A few years later the same date was noted by Capt. Charles Barnard, a whaler from Nantucket. Barnard was marooned on New Island for two years and in a narrative recounts collecting the albatross and penguin eggs on which he survived. His description leaves little doubt that he was referring to the New Island colony. Nearly two hundred years later, the peak egg-laying date for that colony is still October 10.

At Beauchene Island, on the southeast side of the archipelago, the exact date of egg laying is not recorded, but the first chicks hatch on December 5, some ten days earlier than in colonies on the western side of the archipelago. With an incubation period of sixty-eight to sixty-nine days, the probable laying date for Beauchene Island is in late September. Studies I carried out on the rockhopper penguins nesting alongside the albatrosses displayed the same time differential. Those on Beauchene Island were found to be some twelve days earlier in their breeding cycle than those at New Island and the Jason Islands on the west side of the Falklands. I believe that this difference in the breeding cycles of two major species, at two sites situated only 150 miles apart, is further evidence of the link between colony site and food availability. My rockhopper studies had already shown that in the early stages of chick rearing, adult birds foraged largely for krill. Later in the season, an abrupt dietary change took place. Suddenly the colonies became stained with the purplish excreta of a diet of squid, which I suspect had just migrated into the birds' foraging range.

In the last three years, a very large fishing industry has erupted in Falkland waters. The main quarry of this industry is

An island on the western end of the Falkland archipelago supports a huge albatross colony along its coast, right. Millions of seabirds now must share the plentiful fish, krill, and squid offshore with a burgeoning fishing industry. Black-browed albatrosses scavenge in the wake of a squid trawler, below.

the short-finned squid *Illex* and the Patagonian squid *Loligo*. Because both species are important prey of black-brows, penguins, other seabirds, and seals, overfishing could have disastrous effects on this wildlife; rockhopper numbers have already declined in some colonies. Ironically, in another way the fishing industry is assisting indirectly in efforts to understand more about the feeding ecology of our seabirds.

As a fisheries management measure, vessels working in Falkland waters are required to give details of their catches. Their daily positions and the amounts and species taken are recorded and analyzed. Slowly, a pattern is developing showing the movement of marine resources, and the information fits in remarkably well with what we already know about the movements and feeding of different species of penguins, seals, and albatrosses. One of the best examples involves *Loligo*. I had suspected that the abundance of this small squid was important enough to control the breeding timetables of black-brows and rockhoppers. Now, immediately off Beauchene Island, with its 1.5 million seabirds estimated to require some 60,000 tons of food annually, the fishing industry has confirmed the existence of an extraordinary number of *Loligo*.

During my studies on Beauchene, I have watched twenty or more trawlers plying a small area that lies on the shelf edge and catching *Loligo* almost exclusively. Thousands of black-brows follow the trawlers. The birds' ability to scavenge waste from the outlets of the on-board processing plants is at present to their advantage. Nestlings and fledglings, in turn, will also benefit. After being fed for sixteen or seventeen weeks, the young albatrosses leave their nests in April, in the austral autumn. Suddenly they must forage for themselves at sea. The *Loligo* fishing season continues for some weeks after the young birds have vacated the colonies, so these recently fledged albatrosses may also reap some good by scavenging in the wake of trawlers. Evaluating the effects on albatrosses, however, will take time. The young will not return home for five or six years; two or three years after this they may successfully breed.

Ultimately, both the fishing industry and albatross survival depend on finite marine resources, in particular on the squid, an animal with the ability to reproduce in vast numbers, but one also subject to population crashes if overfished. For thousands of years, the black-browed albatross has lived in balance with its food supply. I believe that in the Falklands, this magnificent bird, a symbol of the southern oceans, could also be one of our most valuable gauges of marine abundance and diversity, not just for the fishing industry, but for use in the future management and conservation of ocean life. □

The Unkindest Sting of All

When one scorpion stabs another, it is more a matter of hunger than betrayal

by Gary A. Polis

As I walked over the desert sand dunes, I spotted two scorpions some fifteen feet away. Caught in the ultraviolet (UV) light cast by my portable black light, the animals were brightly fluorescent. The night was perfumed with the fragrance of desert primrose and sand verbena. Coyotes were singing to one another and a great horned owl flapped silently overhead. The constellation Scorpio guarded the southern skies, and the stars were so bright, the owl cast a shadow. At such times, the desert is an enchanting place, full of life and beauty. It is also, however, a violent place.

As I approached the two scorpions, I could see that they were fighting. Eventually, the larger animal overpowered its smaller opponent and began carefully probing with its stinger for a soft, vulnerable membrane. Then, with the deliberateness of a surgeon, the victorious scorpion inserted its stinger and injected paralyzing venom. Within a minute, the victim stopped struggling and the victor started to eat it. The meal might last for hours, for like other arachnids, scorpions use enzymes to digest their food externally before pumping in the soupy remains of their prey.

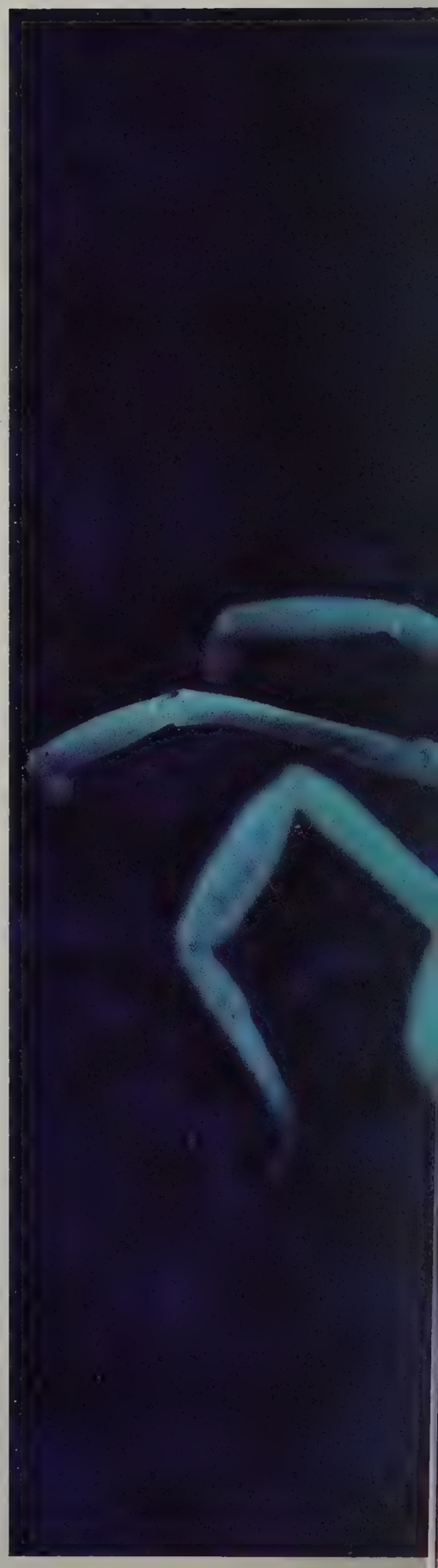
Death on this otherwise calm night seemed incongruous. Yet I had witnessed similar scenes a dozen times that night: of the twenty-five individuals of a small, rare scorpion species I had come across, twelve were in the process of being consumed by individuals of a larger, more common species. After more than a decade of study, I am convinced that such aggression—which occurs both between and, cannibalistically, within species—is one of the major factors shaping scorpion ecology.

In the deserts of western North America, where I have done most of my research, nocturnal scorpions, spiders, and solpugids (sun spiders) form what ecologists call a guild. By definition, members of a guild (named after the medieval unions of artisans that specialized in one craft) use similar resources, which most often means they feed on the same kinds of food. Guild members can interact in several ways, ranging from cooperation and mutualism to competition and mutual predation. Where I work, scorpions, spiders, and solpugids all feed on the same species of arthropods; they also eat one another. One of my research goals has been to determine how such "intraguild predation" influences the distribution and abundance of guild members, especially the scorpions.

Worldwide, there are 1,500 species of scorpions, about 25 of which carry venom that is potentially lethal to humans. Before the development of antivenoms in the last twenty years, thousands of people died of scorpion stings every year in Mexico, Brazil, North Africa, and India. The sting of most scorpions, however, is less painful than that of a honeybee, and from a scorpion's point of view, people are of little interest. Scorpions are after more edible fare, which is basically whatever they can subdue, typically a variety of insects (beetles, wasps, moths, crickets), spiders, and other scorpions. Occasionally, they also eat small reptiles and mammals.

In many parts of the world, scorpions are abundant. Many tropical and desert species occur at densities of one every square yard or so (in some desert areas, it would be difficult to put a sleeping bag down without encountering a scorpion). And many of these places are rich not only in numbers of individuals but also in numbers of species. The scorpion fauna of Baja California is the most diverse in the world, with a total of sixty-one species; in any one area, up to thirteen may occur together.

The desert sands of California's Coachella Valley, my major field site, are home to four species of scorpions. One of these—the sand scorpion (*Paruroctonus mesaensis*)—makes up 95 percent of scorpions in the area. The other three species—*P. luteolus, Vaejovis confusus,* and *Hadrurus arizonensis*—are much rarer. The sand scorpion is moderately large (adults are up to three inches long and weigh up to 4 grams); *P. luteolus* and *V. confusus* are small (one to one and a half inches; 0.2 to 0.4 grams); and *H. arizonensis*, also known as the hairy scorpion, is the largest species in all of North America (up to five to six inches and 16 grams). To investigate how these four species influence one another's whereabouts



Photographed under ultraviolet light, two sand scorpions engage in deadly battle.
Raymond A. Mendez

After injecting paralyzing venom into its victim (a member of a different scorpion species), a sand scorpion starts to dine, right. Below: Hawkmoths and other insects also figure prominently in the scorpion's diet.
Both photographs by Gary A. Polis

and numbers, I spent more than 3,000 hours following them. During those hours in the field, I have seen scorpions killing and eating other scorpions more than 300 times. Overall, I found that from 12 to nearly 50 percent of the diet of these four species consists of other scorpions, of both the same and different species.

Scorpions are very satisfying creatures to the field biologist. When exposed to UV light, their exoskeletons reradiate the light, producing an eerie yellowish, greenish, or bluish glow that can be seen up to thirty feet away on a dark night. As I pan the desert with my black light, I often see constellations of ten to twenty scorpions. Fortunately, the light does not appear to influence their behavior.

Scorpions are also very obliging when it comes to investigating their reproductive success. Individuals mate for the first time two to six years after birth. After a long gestation (from three to twenty-four months, depending on the species), mothers give birth to live young that are larger than those of almost all other terrestrial arthropods. The number born ranges from one to more than one hundred young, with most species having fifteen to thirty. The young complete their development on their mother's back for a period of a week to a month before becoming independent.

The four Coachella Valley species mate at different times of the year, but all give birth in midsummer. Within each species, all the young are born more or less synchronously, over a short period of two weeks or so. Newborn sand scorpions, for example, begin appearing in late July, and by mid-August, the sand is crawling with them. They will all grow pretty much at the same pace for the next two years, by which time they will be mature. Because of the birth synchrony and uniformity of growth, it's easy, at any one time, to divide sand scorpions into three age classes: young (under one year); intermediate (one to two years); and adult (two to six years). (Scorpions generally live for three to seven years, although some have been reported to survive for twenty-five years or more.)

Most other species of desert scorpion also produce young synchronously and exhibit several distinct age classes. These

Scorpions bear live young, which then clamber up onto their mother's back, where they may stay for up to a month before striking off on their own.
C. Ross

divisions, corresponding to the animals' size more than anything else, enabled me to study how age classes differ. What I found was that the three age groups of sand scorpions are as different from one another—in ecology and behavior—as if they were different species. They capture different prey, suffer different predators, emerge to the surface from the burrows at different times of the night and year, and occupy different microhabitats. At 11 mm, for example, newborn sand scorpions catch small wasps and beetles (about 5 mm); as adults, they feed on prey about three times larger, two-thirds of which are different species (such as large spiders, solpugids, and beetles).

These size- and age-based differences help to explain why scorpions are so prone to kill and eat one another: smaller individuals, regardless of species, count as nothing more than a potential meal for bigger ones. And in a fight between scorpions, size is all-important. During a fight, each combatant grasps the tail of the other with its pincers, attempting to fend off the deadly stinger. Inevitably, the larger individual, able to exert more leverage with its tail, manages to insert its paralyzing stinger. All species are vulnerable when young and small. Early in its life, for instance, a *Hadrurus* is an easy victim of both intermediate and adult sand scorpions. But when those few hairy scorpions that survive their troubled youth grow up, the tables turn, and they often capture and eat all sizes of sand scorpions.

Even with formidable adult *Hadrurus* around, however, sand scorpions are the most frequent predator of other scorpions. During several monthly periods of observation at one location, up to half of all prey caught and eaten by sand scorpions were other scorpions. About 10 percent of these were fellow sand scorpions. In fact, this cannibalism is so intense, it appears to limit the population of sand scorpions. I wondered what effect sand scorpion predation might have on the abundance of other, rarer species. Our direct observations suggested sand scorpions took a heavy toll. For example, throughout the entire study, 6 percent of all *V. confusus,* 8 percent of all *P. luteolus,* and 10 percent of all newborn *Hadrurus* ever seen were actually being eaten by sand scorpions when I, or one of my co-workers, came across them. (This contrasts with 0.01 percent of sand scorpions that are eaten by other species.) To test whether the relative rarity of these three species may be due to predation by *P. mesaensis,* I removed more than 6,000 sand scorpions (imagine a bucket with almost seven pounds of scorpions) from certain areas of the desert during a two and a half year period. The results were clear. *P. luteolus* became more than six times more abundant than in control areas; *V. confusus* was about one and a half times more abundant. (The hairy scorpion was too rare for me to quantify the effect on it.)

Scorpion–scorpion predation also influences the distribution of smaller species and younger age classes, which generally avoid being out either on open sand or during late spring and early fall, when adult sand scorpions are most abundant. Forced into marginal areas, smaller and younger scorpions thus forage most often during the colder parts of the year and in soils with more gravel. Unfortunately for them, insect prey is most plentiful on sand and during the warm months, so avoiding predation is not without its costs.

Sometimes the smaller scorpions are unable to avoid exposing themselves to the sand scorpions. Adult sand scorpions, for example, normally enter their burrows in September and don't come out until March or April, leaving *P. luteolus* free to mate undisturbed during the dark period of the new moon in early October. During this time, males walk about the surface in search of receptive females, which emit pheromones to guide their suitors on their way. During the courtship, the male uses his claws to grasp those of the female and leads her in a prolonged dance until they find a hard surface, such as a small stick, on the sand. The male then glues a 2- to 3-mm sperm-bearing structure on the stick and drags the female over it. She opens her genital aperture, descends on the spermatophore, and aspirates the sperm into her reproductive tract. Almost immediately, the male violently bats the female with his tail and runs away; if he is not fast enough, she may catch and eat him on the spot. In most years, the greatest threat to the male is his mate, but in other years, he may successfully escape the female only to run right into the pincers of a hungry sand scorpion. For if the fall is unseasonably warm, adult sand scorpions may still be foraging actively on the surface in October rather than tucked away in their burrows.

In the shadow of San Jacinto Mountain, California's Coachella Valley appears barren, but it is rich in animal life, including four species of scorpions. To locate prey, scorpions "listen" to vibrations in the desert sands, much as a seismologist pinpoints earthquakes.

Gary A. Polis

Less dramatic, but more common, is the danger small scorpions face during stressful periods when prey is scarce and everyone is hungry. The hungrier an animal is, the greater the risk it will take to get food. For the smaller and younger scorpions, this may mean venturing forth from the marginal areas they normally inhabit into sand scorpion territory. And no matter where they are, they will probably have to forage longer to find enough to eat. The more they move around and the longer they spend on the surface, the greater their chances of becoming another scorpion's next meal.

Unlike the ample evidence that scorpions eat one another, I have found none to suggest they directly compete for food, the usual hypothesis proffered to explain patterns of distribution and abundance. Other studies have shown that predation on potential competitors occurs to varying degrees in such diverse groups as protozoans, zooplankton, spiders, insects, fishes, salamanders, reptiles, birds, and such carnivorous mammals as lions and hyenas. For many of these other species, the threat of predation, or the opportunity to prey on a predator, may be the paramount biological factor determining where they occur and how many there are. It may be a dog-eat-dog world after all. □

Some scorpions hide under rocks until an unsuspecting victim—in this case, a younger member of the same species—happens by.
Raymond A. Mendez

L.L.T. Rhodes; Animals Animals

Beware of Well-fed Felines

Britain's five million house cats enjoy both indoor comforts and outdoor hunting

by Peter B. Churcher and John H. Lawton

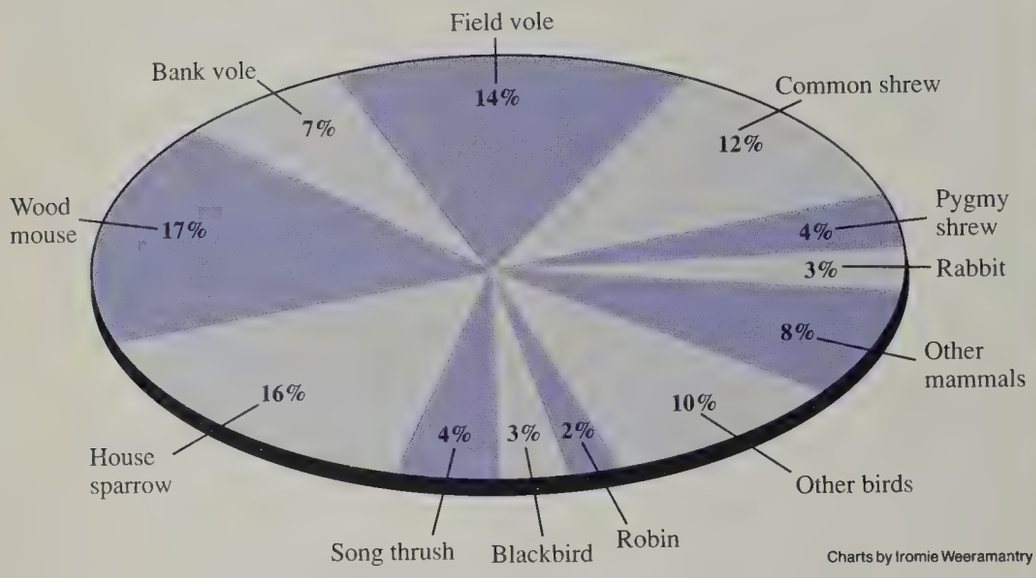
Although the resident cat in the Churcher's Bedfordshire village household was well-fed, she insisted on supplementing her diet with birds and small mammals. These she brought into the kitchen and consumed beneath the table to the sound of crunching bones.

Especially during the summer months, there was great competition among the family members not to be the first to go downstairs in the morning because all too often it entailed having to clear up the remains of the previous night's catch. This might be anything from a pool of blood and some nameless part of the digestive system of a luckless mouse to a live and very frightened baby rabbit. The rabbit had presumably played possum while in the cat's jaws and then limped off behind the fridge when the cat stopped to catch its breath after negotiating the intricacies of the cat door.

The Lawtons, too, had well-fed Yorkshire cats that littered the kitchen with corpses, and we reasoned that if all of the domestic cats in the country caught as much prey as ours did, they might be having a very significant impact on the environment. The first step was to look in the scientific literature to see what work had been done on the feeding habits of domestic cats. The answer, surprisingly, was very little.

While a lot is known about the behavior

Cat Prey in a Bedfordshire Village



Charts by Iromie Weeramantry

and physiology of cats, and many studies have been done on the feeding of their larger relatives, the importance of the house cat in ecosystems has been neglected. A good deal has been written about the impact of owls, foxes, and the mustelids, but in towns and villages, larger predators such as these are scarce. Perhaps cats are more important players on the ecological stage than they have been given credit for, particularly in urban and suburban environments.

Most of the studies have focused on feral cats, that is, animals that have run wild and live more or less independently of humans. While these cats have a marked effect in some systems (for example, the impact of feral cats on the birds of some oceanic islands has been devastating), feral cats in Britain are probably not common enough to be significant natural predators. And certainly their numbers are low compared with the five million British cats living as pets.

The reason for the lack of cat studies is not hard to understand when you consider the way scientists usually carry out studies of feeding in predatory mammals. They either look at gut contents, for which they need a large sample of dead animals (usually obtained from pest-control programs or road casualties), or examine droppings. This latter technique at least has the advantage of allowing the scientist to obtain data over a period of time (dead animals can only yield one reading), but it is laborious, unpleasant, and difficult to quantify. Our technique, which involved recording the animals brought home by the cats, seemed to get around these difficulties and was more likely to elicit cooperation from other pet owners.

We decided to make an intensive study in the small Bedfordshire village where Peter lived. This began with a survey to see how many domestic cats there were in the village and whether their owners would be willing to participate. In the 173 houses in the village there were 78 cats, a slightly higher incidence of cat owning than in Britain as a whole. Only one cat owner refused to take part in the study, which was to take one complete year. Our pilot study, conducted on a small number of cats, convinced us that the project was feasible, and the work began in earnest in June 1981.

We gave each cat owner a consecutively numbered supply of polyethylene bags marked with the cat's code letter. We then asked the cat owners to bag the remains of any animals that the cat caught and we collected the bags weekly. In addition, we recorded any catches for which there were no remains. Thus, if a cat was seen to eat the entire specimen, this was

A Florida pet returns home with a squirrel. The family cat has a major impact on urban and suburban wildlife.
Michael H. Francis

A British cat plays with a victim. Mice and other small mammals fall prey to domestic cats more often than birds do.
Stephen Dalton: NHPA

recorded as an "unknown." In this category were also any remains that proved impossible to identify. Identification was straightforward for the vast majority of specimens although initially—the study began during the summer months—it was rather smelly.

The villagers were much less squeamish than we had expected. By the end of the year most were adept at picking up the grisly remains, and several thoughtful individuals even went so far as to place their cats' trophies in home freezers, making the job of identification a good deal more pleasant. We had some concern that after twelve months of the study the owners would become bored with the daily task of putting corpses into bags or that the cats' catching efforts might be affected as a result of having their prey repeatedly taken from them. As it turned out, these worries were groundless: the total number of specimens caught during the last month of the survey was virtually identical with the total eleven months earlier.

The major prey of these cats—some 64 percent of the annual total—was small mammals. Wood mice, field voles, and common shrews were the most common victims. Contrary to folklore, birds were always in the minority, except during the coldest part of the winter when small mammals are inactive above ground. Exotica included weasels, pipistrelle bats—one enterprising cat with a taste for the unusual caught virtually no other type of prey!—and a kingfisher. The ranking of the species caught may reflect their relative abundance in the area (and as such might be used as a means of gauging prey density) but is complicated by questions such as how easy a species is to catch and its palatability to cats. Most cats appear to be opportunistic hunters, making use of whatever prey is available at the time.

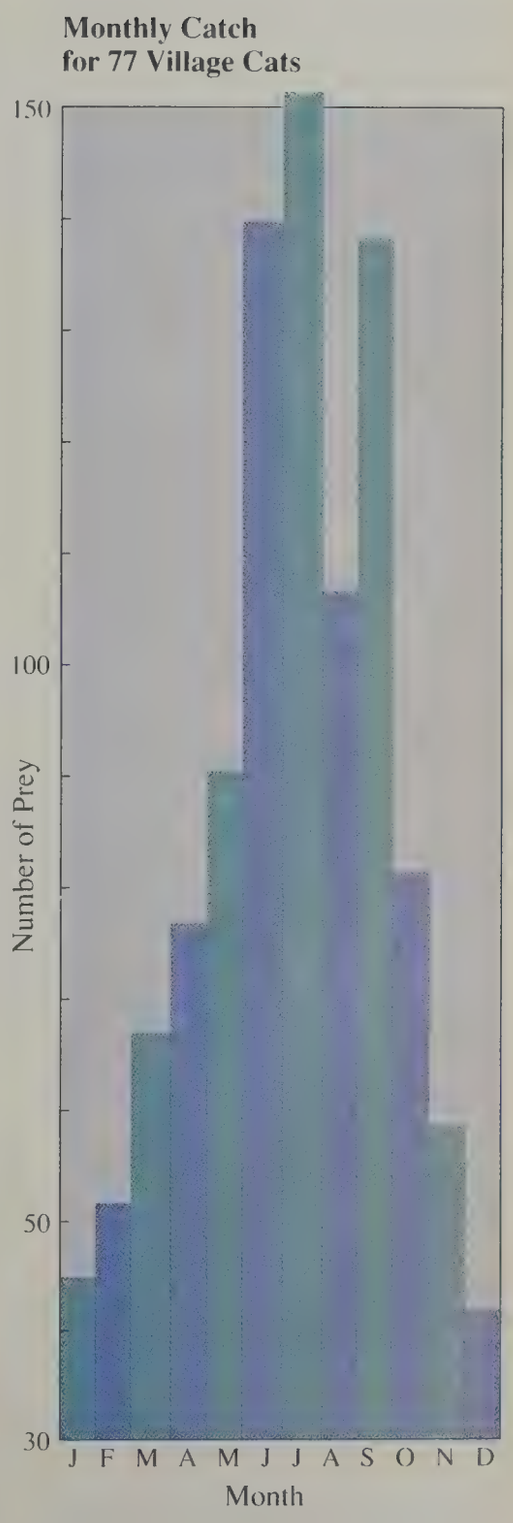
Some cats failed to bring anything home during the year (although it might be more accurate to say that their owners failed to find anything), while some cats contributed up to 100 prey items out of a total of nearly 1,100. (But this is by no means a record. Since our work was first published in *The Journal of Zoology,* several people who own supercats have written to us; the record is currently held by a cat from Dorset that brought home more than 400 prey items in one year. These proud owners seem quite unperturbed by the slaughter.)

What makes a cat a good hunter? Part of the answer is its age. Old cats get lazy; the younger the cat, the more animals it catches. Although we looked only at catches of birds and mammals, several owners reported that their kittens practiced their hunting skills on frogs or butterflies, but only a few of them persisted with these types of prey into adulthood. Sex and neutering did not appear to have a marked effect on hunting success. Our small sample sizes meant that there was no certain way of telling what effect coat color had. Thus we could not solve the old questions of whether black cats are better hunters because they cannot be seen at night or whether cats benefit from cryptic or disruptive coloration. We believe, however, that if there are any advantages conferred by coat color, they are not particularly marked.

Where the cats lived did affect both the type and number of prey brought home. Cats in the middle of the village, without easy access to open ground, caught fewer items in total and proportionally fewer small mammals and more birds. This pattern was reversed for cats living at the edge of the village. The density of the cats themselves seemed to have a slight effect on catching success, with cats in areas with more competition for prey catching fewer items.

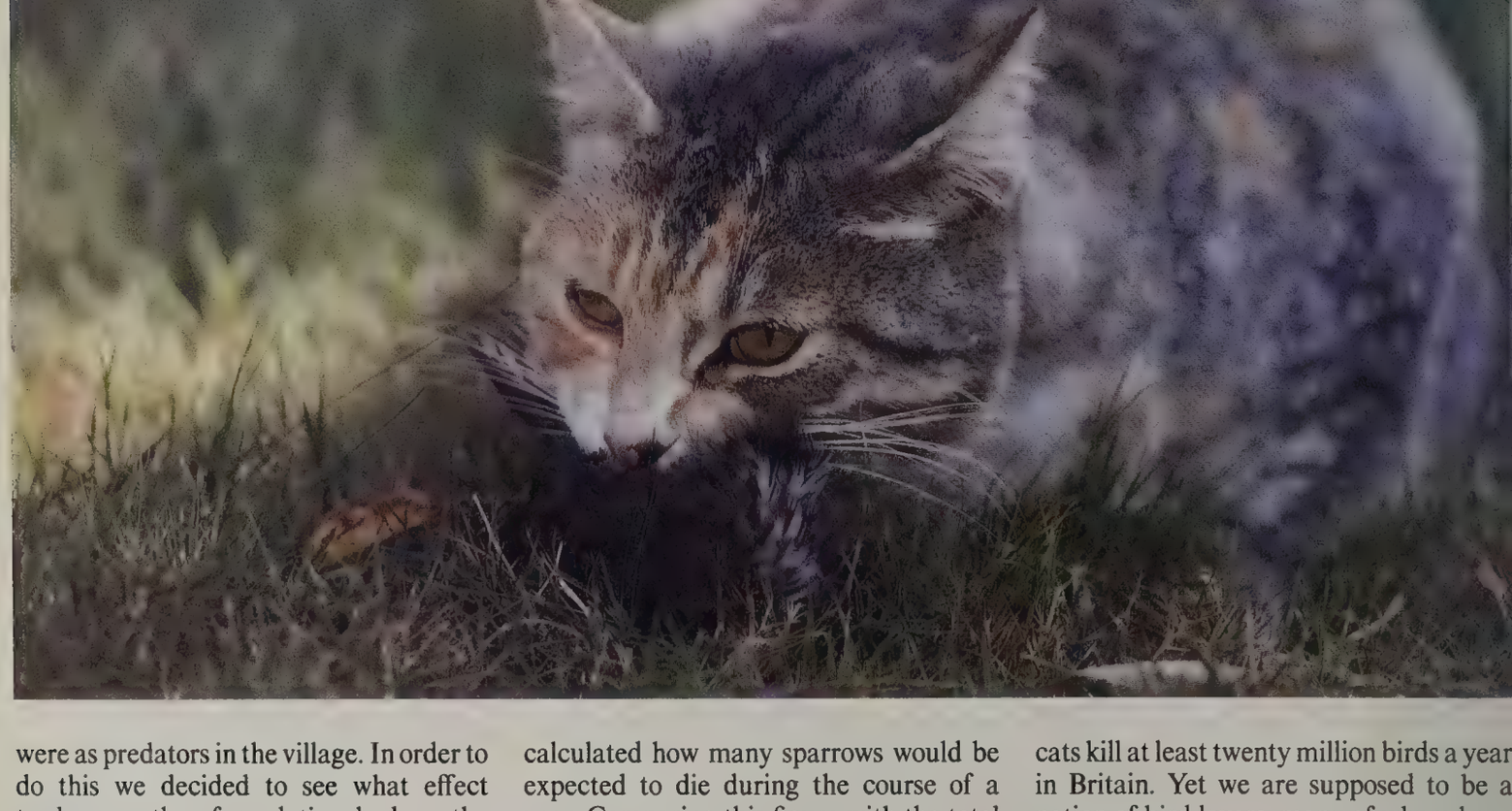
All of the cats were fed by their owners. Although we did not study it closely, the amount of feeding did not seem to affect the catching ability of the cats. Whatever drives cats to hunt, it would seem that it is not just hunger. Well-fed and apparently contented cats are often ruthless killers. But even domestic killers like their home comforts. Rain and wind decreased the kill rate and casual observation of our own cats suggests, not surprisingly, that they spend little time out of doors on wet and windy days.

We soon had a lot of information about what animals the cats caught, but we had no way of telling just how important they



From a convenient perch, a tabby surveys its territory.
David Nadig; Photo Researchers

A cat nabs a bird in British Columbia. Cats were responsible for a third to a half of all sparrow deaths in the authors' study village.
J. R. Page; Valan Photos



were as predators in the village. In order to do this we decided to see what effect twelve months of predation had on the house sparrow population of the village. Although at 16 percent of the total catch, house sparrows were less important prey than wood mice, we felt they would be easier to count than small mammals. The village was divided up into squares of two and a half acres. Just after dawn over a ten-day period in early April (the start of the breeding season, when the sparrows were "out and about," courting and feeding), we counted them in each of ten squares. This allowed us to estimate, with reasonable accuracy, the total house sparrow population in the village.

Working on the assumption that the number of sparrows in a year's time was likely to be roughly the same as the current level, and using extensive published data on sparrow population dynamics, we calculated how many sparrows would be expected to die during the course of a year. Comparing this figure with the total number of sparrows that cats caught in the village, we found that between a third and a half of all sparrow deaths were attributable to cats. This figure seemed staggering: it is highly unlikely that any other single predator could have this much impact on the house sparrow population of the village.

To get some idea of the importance of domestic cats as predators over the whole country you need only to multiply the mean annual catch of the village cats by the estimated total domestic cat population of Britain. This comes out to about seventy million deaths. Of this, between 30 and 50 percent may be birds, depending on whether we are dealing with an urban (center of the village) or more rural (edge of the village) situation. So domestic cats kill at least twenty million birds a year in Britain. Yet we are supposed to be a nation of bird lovers, many of whom keep cats but still castigate bird hunters and trappers on the continent of Europe.

Worse still, we doubt that the owners would find, or that the cats would even bring home, all of their catch. An American study, in which a biologist looked carefully at the feeding habits of his own farm cats, found that they brought home only about half of their total catch. They either ate the rest on the spot or left it to be scavenged by other animals. If such a figure is relevant to our work, our tentative calculations may be serious underestimates and the importance of domestic cats as predators may be even greater than our results have suggested. The delightful, well-fed, domestic cat may be the major killer of small birds and mammals in urban and suburban environments. □

The Once and Future Museum

Shuttered and abandoned for more than thirty years, France's spectacular zoology gallery tries for a comeback

Text by Carl Gans • Paintings by Jürg Kreienbühl

Between the nineteenth-century Gare d'Austerlitz and the modern buildings of the University of Paris, the Jardin des Plantes stretches almost a mile from the Seine to the Great Mosque of Paris. Here the casual tourist can discover nicely manicured walkways, an array of statuary, enormous greenhouses, a small zoo and a botanical garden, shaded nooks where *rentiers* meet daily to play cards or checkers, and various exhibition halls, all fringed by houses of various ages and architectural styles. Yet the palatial Grande Galerie de Zoologie, which crowns the park the way the U. S. Capitol crowns the Washington Mall, is closed and unmarked; its identity, as well as the importance of the Jardin des Plantes to the history of zoology, remains undisclosed to the general public.

In 1635, this sizable piece of land was set aside by Louis XIII as a *jardin du roi*, the site of an institution for the instruction of physicians and the scientific study of medicinal plants. Gradually, this emphasis broadened and shifted to the study of natural history, a process that was completed during the mid-eighteenth century, when the institution was led by the naturalist George Louis Leclerc, comte de Buffon, whose multivolume treatises on animals were standard reference books for more than a century.

The "garden of the king" became the National Museum of Natural History at the time of the Revolution, reflecting the idea that its staff and collections served the people through exhibitions and other modes of popular education. Five of the curators then were named "professors"; their number gradually increased to nine by the middle of the following century. Curators were allowed to do research and lecture, sometimes under other auspices. Even today French science is a curious mix of teaching, curatorial, and research requirements, with many participants holding multiple appointments.

The shift to professors meant more money and the ability to increase supporting staff. The names of Lamarck (a founder of evolutionary theory), Geoffroy Saint-Hilaire (a founder of theoretical morphology), and Duméril (cataloger of the lower vertebrates) became known to every zoologist; the works of their colleague Cuvier made him known as the "father" of both comparative anatomy and paleontology.

The new professors now had the resources to review their fields. They could describe more rare species, and do it bet-

"In the courtyard one could see whale skeletons, giraffes, giant sharks—the largest and most magnificent organisms inhabiting our planet."

ter, based upon actual specimens rather than historical documents; they could also generate compendiums comparing the new with the old. The need to document and compare inevitably established a need for collections. These increased the rigors of a previously diffuse field. Not only were the actual specimens available for future checks of the original descriptions; they also could be used for anatomical studies as researchers started to analyze additional internal organs. Rather than describing the anatomies and functions of whole animals one after another, as in the compendiums of Buffon, the new comparative anatomists concentrated on eyes or legs or guts, comparing vision, locomotion, or digestion across taxonomic groups. These changes led not only to a new viewpoint but also to the accumulation of extensive collections, soon expanding beyond European materials to include those of other continents. Some collections reflected the travels of French soldiers and merchants and the willingness of other curators to exchange "duplicates." Others resulted from the new respectability of natural history and the commitment of scholars and explorers to visit far-off sites and assemble objects characteristic of their natural history. Even more important were the collections acquired by merchants and noblemen: some collected out of a genuine interest in the subject; others to add to their own renown.

One of the last such explorer-collectors was Louis Philippe Robert, duc d'Orléans (1869–1926), who initially housed his collection in a private museum that was later donated to the French nation with the proviso that the building remain dedicated to exhibition and the collection maintained. Unfortunately, the interest in separate collections flagged, and much of the duke's collection was scattered.

Grande Galerie de Zoologie

The lack of adequate housing for the increasing number of staff members, who were traditionally provided with living quarters on or near the museum grounds, was a constant problem. Hence, the ever-expanding zoological collections had to be housed in a series of buildings close to the various research facilities. This, in turn, led to a continuing conflict between the need for storage space and the need for research space for the professors. The resultant diffusion of specimens did not facilitate exhibition and thus interfered with the educational aim of the institution.

Few museum visitors realize that for every specimen exhibited, dozens more are likely to be stored behind the scenes, often unmounted and preserved in alcohol, or as skins, skulls, skeletons, and dried specimens. Materials assembled by expeditions, frequently under trying circumstances, are not always spectacular or complete enough to be displayed to the public. The rarest specimens cannot be exhibited because they must be protected from the damaging effects of light, dust, insects, vibration, and chemical change. Also, a collection must contain enough individuals so that the zoologist has examples of both sexes, of juveniles and growth stages, and of individual and geographical variants. And the study of comparative anatomy requires extras for dissection. In short, research and exhibit collections are distinct but complementary.

At the National Museum, the absence of a unified exhibit collection was an issue that came to a head in the last decades of the nineteenth century. To deal with the problem, a number of exhibition halls, of a size and style matching the garden, were built. The Grande Galerie, a building intended to display the diversity of the world's animal life, opened in 1889. It was followed by ancillary buildings; those housing the exhibits of paleontology and comparative anatomy were located at the other end of the garden next to the Seine, and were probably the most spectacular.

The architects and builders of the Galerie used iron and glass, the most up-to-date materials of the time, and their efforts in designing and executing the plans reflected their skill at overcoming the technological limitations of the period. The key point was that all of the exhibits had to be viewed by natural light. The exhibit halls had no gas lighting, and electric lights were not yet available. To compensate for this, the planners erected a stone-faced shell, surrounding rectangular galleries cantilevered out over an enormous courtyard. The raw material was cast iron, permitting a sculptured pattern in which five galleries were supported by fluted and headed columns and fringed by crenelated railings. The central court was roofed with an enormous array of windows supported by an iron framework. This

Peacocks

glass roof reminds one of those in greenhouses and turn-of-the-century railway stations—not surprisingly, since such buildings clearly served as models.

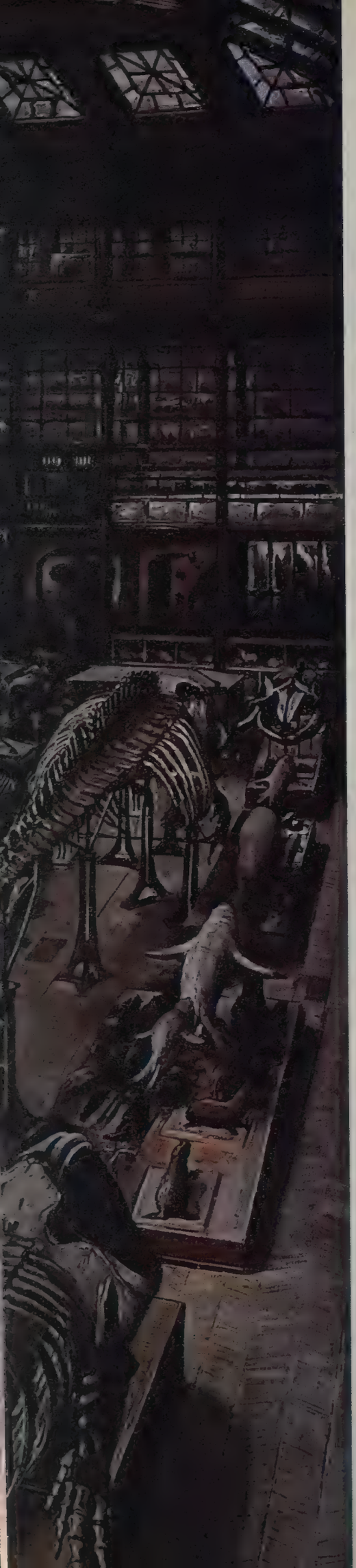
Construction of the Grande Galerie, and the smaller buildings that followed it, marked a return to the museum's original mandate to aid popular education by exhibiting actual specimens. This shift of emphasis was accelerated by the rise of the Third Republic with its efforts at educational reform.

The new galleries provided a great deal of space, which meant that many examples of small and medium-sized species could be displayed according to their classification: frogs next to salamanders; snails next to clams and squids. Wooden and metal vitrines revealed shelves of birds, trays of mollusks and insects, and arrays of stuffed animals. The center of the courtyard, however, provided the most spectacular view. Here one could see examples of the largest and most magnificent organisms inhabiting our planet. A group of enormous giraffes stood in one corner, dwarfed by the dimensions of the hall. Next to them hung five or six gigantic whale skeletons, and even their size was diminished by the huge scale of the courtyard. Many of the exhibits represented extremes in size; proportions no longer encountered now that the species occupy much more restricted ranges. Visitors could walk among wooden ziggurats, each level occupied by large birds, mammals, or reptiles. There were adult gavials and giant sharks. The latter, although exemplifying the best taxidermic skills of the period, document inadequate communication between taxidermists and zoologists. Stuffed, rather than mounted, the sharks lost their streamlined elegance and often looked like gaping sausages.

The exhibition style in this giant hall was essentially static. The approach long antedated the concept of dioramas. Instead, the biology of the animals was sometimes illustrated by murals and small paintings. It was too early to expect the amount of detail that can be seen in the American Museum's Akeley Hall of African Mammals, where each species is accompanied by matching samples of

"Newspapers talked about transferring the museum's whale skeletons by helicopter. Whales over the roofs of Paris!"

Zoology Gallery, *left;* Paleontology Gallery, *below*



"Many exhibits were giants of the rarest forms—of proportions no longer encountered now that the species occupy restricted ranges."

plants, rocks, and soils assembled by a single expedition charged with generating an exhibit rather than performing research. However, the staff of the Paris museum had a strong commitment to the display of creatures as living animals. Thus, one sees the leopard holding its peacock prey, tigers attacking elephants, birds in postures of display.

The Grande Galerie was successful not only because of the number of visitors it attracted but also because it revived popular interest in natural history. Pamphlets, journals, and books of the time document the renewed enthusiasm for animals and curiosity about their habits. Special expositions attracted enormous crowds and were discussed at length in the popular press. The exposition of deep-sea organisms, sponsored by Professor Milne-Edwards, a specialist in marine invertebrates, convinced the public for the first time that the sea was not a depauperate desert but was inhabited by a spectacular and distinct organismic world.

The Grande Galerie represented the most spectacular of exhibitions. However, its very design incorporated the seeds of future difficulties. Maintenance was very expensive. The necessity for a central court exposed the exhibits to sunlight, and decades of bleaching led to the fading of furs. Although protective shading was attempted, it interfered with the appearance of the exhibits. The dome's windows leaked from rain and snow and their glass panes broke, leading to periodic incursions of moisture that damaged not only the specimens but even the parquet floors. The advent of electricity allowed modest supplemental illumination, and some central heat temporarily ameliorated the gradual deterioration. The specimens, exposed for half a century without adequate dust control, required refurbishing.

Unfortunately, maintenance continued to be deferred. During and after World War II, the glass vault leaked regularly, causing further damage to exhibits. To overcome the problem, the roof was covered with sheet metal. While this blocked much of the moisture, it also blocked light, leaving only the interior lighting, which was inadequate. Since major changes seemed impossible, the Grande Galerie was closed to the public in the fifties. Still, some of the staff kept on striving, hoping for a reopening.

Concern about the Galerie was perhaps exemplified by my first view of the hall. I had come to examine some specimens still housed in the classification arrays. The curator being away, things were a bit more relaxed and I was permitted to help the technician push the pram in which jars of snakes traveled the length of the park; he also kindly led me into the Grande Galerie and turned on the very inadequate illumination. I was stunned by the impressionistic display and by many of the individual specimens representing giants of the rarest forms. However, the curator returned the next day. When I suggested that I help bring the next batch of specimens, he objected that it was not appropriate for visitors to see the Galerie in this state.

Indeed, in the decades since its closing, many people lost sight of the Galerie's grand conception. Instead, some argued that the emphasis on antique displays used up a disproportionate share of the resources required to bring the facility up to an acceptable level. One of the main complaints was that the museum exhibited animals in taxonomic series rather than emphasizing general biological principles, many of which had been and were being developed by scientists occupying adjacent buildings. This conflict between the study of principles and that of displaying diversity was evident in all future plans for reconstruction of the Galerie.

In the 1970s the ark was abandoned in earnest. The area of the garden in front of the Galerie was excavated, a four-story underground block of concrete was installed, and the site was hidden by plantings. These catacombs, equipped with special ventilation, fireproofing facilities, and compacting storage cabinets, were hence to be occupied by research materials salvaged from the nooks, crannies, and storage areas of the Galerie. Hundreds of thousands of specimens, whether of turtles or snails, stuffed crocodiles, or elephant bones, reached this new home. Then the contents of the main galleries were gradually shifted. Because many of the specimens were rare and irreplaceable, they needed to be protected from deterioration.

By the end of the 1970s, the Grande Galerie was little more than an empty shell, surrounding a courtyard inhabited by giant remnants. What the fate of these was to be, no one could decide. On one occasion, newspaper stories talked about plans to transfer the whale skeletons by helicopter. Whales over the roofs of Paris! Only the memory of the Galerie's greatness seemed to remain. Then a series of artists started an effort to rescue the shipwrecked ark. Photographers publicized the hall, and the painter Jürg Kreienbühl devoted eight years of his life to a stunning series of paintings celebrating the central hall and its spectacular contents. His exhibition, held in 1985 under the auspices of the museum, attracted great attention in the press and on television. About a year and a half later, the popular singer Renaud organized a sound and light show and dedicated the profits of his activity to a fund for reconstituting the exhibits.

These public efforts supported those on the museum staff who had long wished to retain and build on the spectacular aspects of the Grande Galerie. To them, the National Museum of Natural History was as rich a part of the French patrimony as the spectacular art collections on the other side of the Seine; the scattering of the Galerie's contents was therefore a national loss. Some scientists urged restoring only the more "modern" exhibits, such as those seen in other museums; others suggested an emphasis on current biological technology. But these limited plans did not compensate for the loss of a historic monument.

Now plans have been adopted that both restore the original Galerie displays and expand them to include modern concepts of evolution and ecology. Major renovations are already well under way. The Galerie, in its prime, was a monument to animal diversity, a subject of critical importance today. Its construction marked a milestone in our understanding of the natural history of animals. I look forward to its reopening. □

"The Museum is as rich a patrimony as the more famous art collections on the other side of the Seine."

Bust of Professor Lacaze-Duthiers

Dwelling Places

by Stanley A. Freed

Hiding behind a narrow technical title, *Native American Architecture* is a rich, wide-ranging depiction of American Indian culture, belief, and history. For Peter Nabokov, an anthropologist, and Robert Easton, an architect, architecture is much more than just the technical study of the design, construction, and decoration of buildings. Rather, it is a tangible expression of an entire way of life.

It embraces what happens whenever human thought or action makes order and meaning of random space: naming places, designating sacred parts of "wilderness," clearing village areas and garden plots, claiming food-gathering areas, planning and constructing buildings, and arranging the spaces that surround and connect them. Finally, it includes the often unseen social and religious meanings which are encoded into buildings and spatial domains.

This broad charter allows the authors to move beyond a solid core of architectural description and analysis to consider the views of various Indian tribes about the nature of family, community, and the encompassing sacred universe.

Voluminous descriptions, photographs, and drawings of Native American architecture north of Mexico are scattered through the ethnographic literature and in the archives of museums, historical societies, and research libraries. These diverse data have never been assembled in a comprehensive study, certainly not one like Nabokov and Easton's, whose scholarly, well-written text is complemented by a remarkable selection of photographs, drawings, and paintings. Moreover, the authors have supplemented the archival material by visiting many tribes to interview and take photographs. The illustrations alone make the book a treasure for both the general reader and the specialist.

NATIVE AMERICAN ARCHITECTURE, by Peter Nabokov and Robert Easton. *Oxford University Press, $50.00; 431 pp., illus.*

Many of the photographs were familiar, having been reproduced many times, but I had never before seen most of them, and their detailed captions are one of the finest features of the book.

The authors use the "culture-area" concept to organize their material into chapters. An old standby, the concept is still the most effective way to make the great diversity of Native American life understandable. A culture area is a large geographical region in which similar cultures are found. These regions, such as the Plains, the Arctic, and the Southwest, are characterized by generally similar climate, terrain, flora, and fauna.

To treat architecture in the context of culture areas might imply that climate and building materials determine the structure of Indian dwellings. The authors carefully point out that the environment makes specific architectural forms possible, but not inevitable. Architectural forms can be understood only by considering a variety of what the authors call "modifying factors," of which six are paramount: technology, climate, economics, social organization, religion, and history. Each of the nine culture-area chapters that follow the Introduction interweaves these factors to form the narrative.

Of the six paramount factors, technology is the one that immediately impressed European explorers and formed an initial basis for their estimate of the cultural development of Native Americans. The earliest Spaniards in the Southwest, for example, admired the large, many-roomed, multistoried stone and adobe buildings and the towns, known as pueblos, with their carefully organized public areas featuring plazas and underground religious chambers, called kivas. The large pole, beam, and plank houses of the Northwest Coast are equally impressive both for the expert carpentry required to build them and for their magnificent artistic embellishment. But even simple structures, when closely examined, reveal the noteworthy skill needed to construct them and their effective adaptation to their environment and way of life. The Plains Indian tipi, superbly adapted to a nomadic life on the Plains, is a case in point. The women who prepared the buffalo-hide tipi covers were skilled artisans.

Although not often apparent in details of construction, social organization and religion played a part in Indian architecture. The roles of men and women in the construction and ownership of dwellings were usually well defined and differed among tribes. Even within dwellings that lacked internal partitions, specific sleeping areas were reserved for married couples and for single people, there were des-

Smithsonian Institution

Painted buffalo-hide tipi cover, above, was used on the Great Plains. Lightweight canvas, replacing hide, allowed for larger structures, like the Flathead tipi, opposite. Dance garb hangs from the poles.

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(can't say you weren't forewarned)

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Santa Barbara Museum of Natural History; E. S. Curtis

Stilt-supported Eskimo homes on King Island overlooking the Bering Sea, ca. 1928. Houses are plank-framed boxes wrapped with walrus hide. Below: A Maidu roundhouse in northern California.

ignated places for sacred objects, and other areas were set aside for the storage of mundane utensils. The role of religion in Native American architecture is seen chiefly in the variety of religious structures, such as the sacred stomp grounds of the Southeastern Indians with their sheds; the underground kivas of the Pueblos; the roundhouses of the California Indians; huts for the seclusion of menstruating women; sweat houses for purification; and the large open enclosure set up for the Sun Dance, the great summer ceremony of the Plains Indians.

Each of the nine culture-area chapters follows the same general format. A chapter begins with a brief anecdote of early European exploration, some archeological material might be given, basic ethnographic information is introduced, and then the various structures are taken up one by one, for in most areas, the Indians made use of two or three types of dwelling. The authors generally connect descriptions of structures to specific tribes, thus maintaining ethnographic context. Finally, the authors bring their account up to the present day.

The Northwest Coast chapter is typical. A long, narrow strip of territory along the North Pacific coast from southern Alaska to Oregon, the Northwest Coast is culturally divided into three principal subregions: Southern, Central, and Northern. Treatment of the Southern region begins with an account of Capt. George Vancouver's 1792 visit to the Dwamish (Salish) near Seattle, where he inspected an enormous house with the traditional single-pitch shed roof. This one building sheltered more than 600 people and was more than 380 yards long. The interior was divided into eight sections, each of which housed a clan, identified by a totem pole. A technical description of this style of house is well illustrated with paintings,

Peter Nabokov

photographs, and drawings. The authors briefly describe the effects of European settlement on native architecture in this region. Buildings with gabled or mansard roofs, based on European styles, came into fashion. By 1900, most traditional shed houses and even semitraditional houses with European-derived features had been burned or abandoned, and the Indians were living in the white man's style of house, known as "Boston houses," or in shantytowns.

Nabokov and Easton deal with the Central and Northern regions somewhat more fully, giving individual attention to the principal tribes, such as the Kwakiutl, Haida, and Tlingit. They continually relate architecture to social structure, ceremonies, and cosmology, although a sidebar about Kwakiutl iconography is too brief to give a feel for the subject. Iconography is important because Northwest Coast houses are heavily decorated with mythical animals and beings that serve as clan crests. Photographs of the famous three-level "Monster House," fifty-five feet square, and the "Whale House," renowned for its artworks, add drama to the account. However, the Whale House photograph is so poorly reproduced that the artistic quality of the huge rear screen can barely be appreciated, and the flanking carved house posts, splendid examples of Northwest Coast art, almost disappear against a dark background.

The authors, who spent more than ten years researching and writing their book, aimed it at the general reader, whom it should please. The narrative flows easily and the illustrations are a delight; my only reservation is that the nonspecialist may become bogged down in ethnographic detail and not really receive a holistic sense of the cultures under discussion. But the illustrations and their captions form a sequence of sidebars that can be read apart from the text. This feature makes the book as useful to specialists as to general readers, for it is convenient to have in one book comprehensive photographic coverage of architectural forms for all the culture areas of America north of Mexico.

The book ends abruptly. A short comparative discussion of the "modifying factors" as they are expressed in the various culture areas would have been a valuable concluding chapter. But these reservations are minor. Readers will find the book interesting and delightful whether they read it closely or simply leaf through it to enjoy the fascinating photographs.

Stanley A. Freed is a curator in the Department of Anthropology at the American Museum of Natural History.

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Prairie dock is one of the wildflowers that grow in Grasshopper Hollow's prairie fen. New England aster, opposite page, is another.

Donald Kurz; Touch Nature Photos

Grasshopper Hollow, Missouri

by Robert H. Mohlenbrock

In the first act of Edward Albee's *Who's Afraid of Virginia Woolf,* Martha describes husband George as "an old bog in the History Department. A bog.... A fen.... A [expletive deleted] swamp." Of these three terms, used interchangeably by Martha, *fen* perhaps stands out as a bit uncommon. All connote a wet, soggy habitat, with *swamp* implying a forested area with standing water and *bog* suggesting an open region quaking with layers of sphagnum moss. Like bogs, fens are mostly open areas, but with an important distinction recognized by many biologists: the groundwater in bogs is acidic, while that in fens is basic, or calcareous.

Early this decade, Southern Illinois University botany student Steve Orzell discovered dozens of areas that qualified as fens in the Saint Francois Mountains region of southeastern Missouri. The most fruitful spot was Grasshopper Hollow, a ravine some eighty-five miles southwest of Saint Louis and two miles northwest of the tiny Ozark community of Reynolds. Here Orzell discovered a series of fens in a 300-acre area. Some of the land is in private hands and some was recently acquired by the Nature Conservancy, but much of it is administered by the Mark Twain National Forest.

Grasshopper Hollow owes its existence to Grasshopper Creek and its tributaries, which have carved deep defiles into the bedrock. Blocks and rock fragments are scattered throughout the area as a result of erosion high on the steep slopes. Water seeps from numerous places near the base of the slopes and, observes biologist Max Hutchison, collects to form small rivulets or spreads out into the valleys to form the fens. Since the bedrock is largely dolomitic limestone, the water that flows through the area picks up carbonate and becomes basic.

The fens in Grasshopper Hollow are of several kinds. The great majority—ten or eleven of them—are open, essentially treeless areas with moderate water that seeps over shoetops. Three others are quite different. One contains so much water and soggy soil that anyone stepping into it will sink to the waist or deeper; Missouri botanist Paul Nelson describes such habitats as deep muck fens. Another, not as wet as most of the others, is dominated by typical prairie plants and has been called a prairie fen. Finally, there is a forested area that on appearances might logically be called a "swamp" but for which biologists prefer the term "forested fen," on account of the calcareous water.

The more typical fens are found on somewhat sloping terrain, in the narrow valleys or on the hills, where groundwater oozes up and fans out. The amount of standing water varies with the degree of slope, from as little as a trace to as much as fifteen inches. Gravel and rock fragments are usually scattered liberally about amongst tussocks of sedges and grasses. Mixed in are several colorful summer- and fall-flowering wildflowers, such as orange coneflower, false dragonhead, swamp goldenrod, golden ragwort, and fen aster.

More forbidding and extremely difficult, if not impossible, to traverse is the deep muck fen, which lies on a flat valley terrace near the foot of a slope. The area is boglike and quaking, with standing water forming small, shallow ponds. The soupy, mucky soil is more than forty inches deep,

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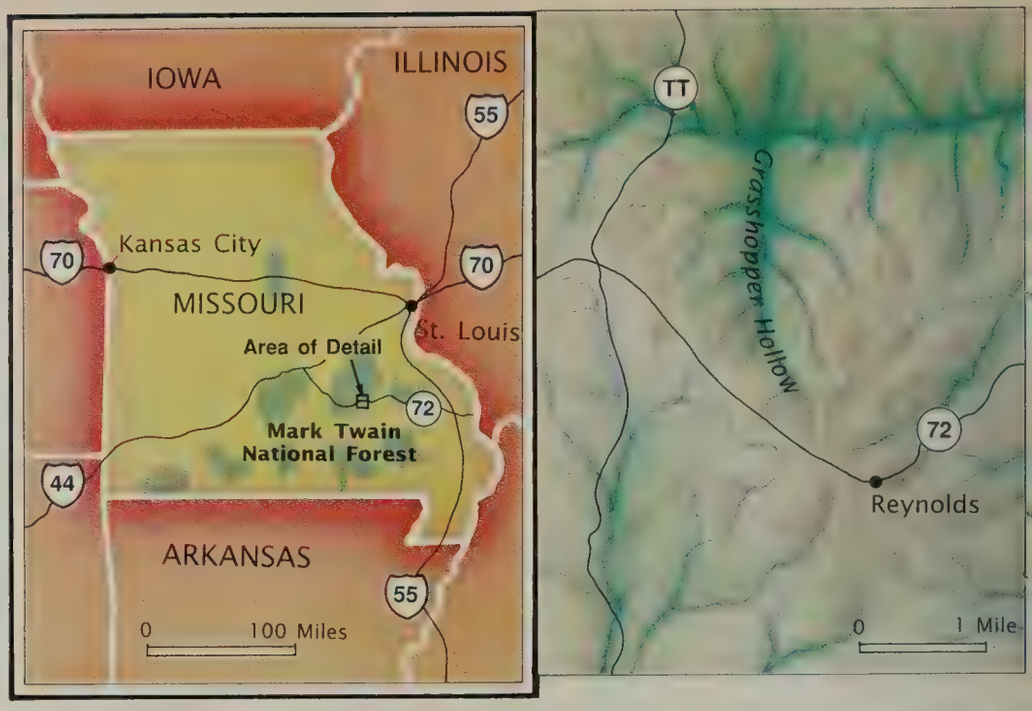

with no surface gravel and rock fragments. Grasses and sedges abound, along with a shrubby alder. One of the most graceful sedges, *Carex crinita,* stands as much as five feet tall, growing with the robust royal fern. Other wetland shrubs are swamp dogwood, silky willow, and buttonbush, while the wildflowers include the speckled wild sweet william.

Grasshopper Hollow's seventeen-acre prairie fen is considered by local botanists to be the most pristine such fen in the world. Prairie fens usually arise along valley terraces with a slight slope. They are easily traversed since there is little standing water and only a shallow layer of mucky soil. What distinguishes them is that the more typical fen vegetation is joined by tall prairie grasses and prairie wildflowers. Orzell and Missouri botanist Donald Kurz have recorded 179 species of plants in the prairie fen in Grasshopper Hollow, more than 20 percent of which are characteristic of midwestern tallgrass prairies. The principal tallgrasses are big bluestem, Indian grass, and prairie cordgrass. A sampling of the abundant prairie wildflowers includes New England aster, prairie dock, rosinweed, prairie sunflower, scarlet Indian paintbrush, butterfly weed, and Culver's root.

In the floodplain adjacent to Grasshopper Creek, where the soil is poorly drained and seasonally saturated, lies Grasshopper Hollow's forested fen. Green ash, red maple, and slippery elm grow up to sixty feet tall and so densely that they form a closed canopy. Such smaller woody spe-

Gary Meszaros

Buttonbush (flower above) and sedges (right) inhabit Grasshopper Hollow's deep muck fen, whose boggy soil poses a hazard to visitors.

Grasshopper Hollow

For visitor information write:
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cies as blue beech, spicebush, and alder fill the mid-layer of the forest. Sedges and grasses are common in the understory, but the conspicuous feature is the continuous cover of clumps of mosses that conceal the soil surface.

Fens have been recognized for many years in northern Europe, but North American botanists did not really begin to distinguish fens from bogs until the 1960s. Those first identified were in areas that, like northern Europe, had a history of Ice Age glaciation: Iowa, northern Illinois, northern Indiana, northern Ohio, and other northerly regions. Even though the eminent Missouri botanist Julian A. Steyermark had reported "calcareous wet meadows" from the heart of the Ozark Mountains in 1938, no one thought of these and other areas in southern Missouri as fens until Steve Orzell studied them in 1981. Only then did scientists realize that fens, among them those of Grasshopper Hollow, existed south of the line of maximum ice advance during the Ice Age.

"This Land" highlights the biological phenomena of the 154 U. S. national forests. Robert H. Mohlenbrock is Distinguished Professor of Botany at Southern Illinois University at Carbondale.

Donald Kurz; Touch Nature Photos

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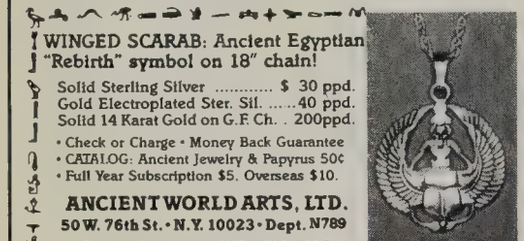
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A Tale by Two Cultures

The dramatic large-format film *The First Emperor,* which premièred at the recent opening of the Canadian Museum of Civilization in Ottawa, is a rare hybrid. The forty-minute spectacular, with its massive battle scenes and colorful reconstructions of Chinese imperial life, is the result of a filmmaking partnership between China Xi'an Studio and the venerable National Film Board of Canada.

The bicultural nature of the project led to some exasperating moments during filming. Canadian producer Barrie Howells recalls the effort and days of planning that went into setting up one scene in which the hero charges out of a swarm of chariots on a black horse. The crew shot the scene once and took a lunch break. During the reshoot after lunch, Howells was astounded to see the hero gallop out on a brown horse. Where, he demanded, is the black horse? The horse's owner replied that he had sold the black animal during lunch—for a good price—because the horse had become a movie star.

Disagreements, or what the Chinese perhaps more accurately call differences of "world view," arose frequently between the Chinese and Canadian filmmakers, but often, says Howells, "we weren't even quite sure what the disagreement was about."

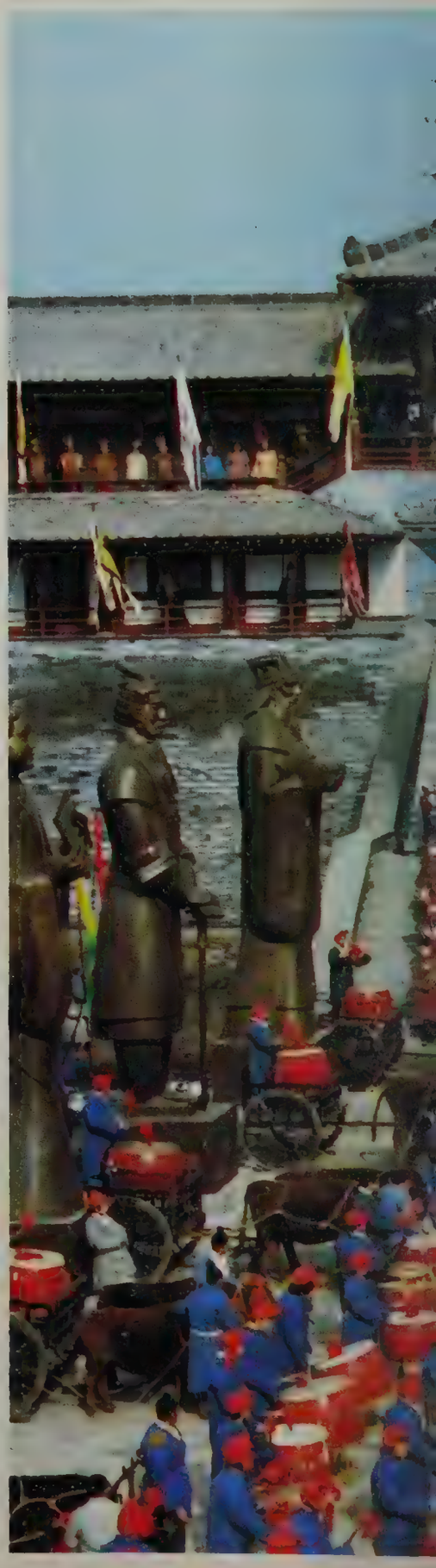
Emperor Qin Shihuang unified China in 221 B.C. and set up the system of imperial dynasties that survived into the twentieth century. During his fifteen-year reign, he constructed a network of roads, built a system of canals that linked northern and southern China by way of the Jinsha Jiang (Yangtze River), and completed the Great Wall. Writing, weights, and measurements were standardized. He reinforced his authoritarian rule by ordering books burned and scholars buried alive. Obsessed with immortality, Qin sought the elixir of eternal life. Ironically, the elixir his alchemists concocted—containing mercury, lead, and arsenic—killed him. But he had prepared for the afterlife by building a tomb complex guarded by an underground army of more than 7,000 terra cotta soldiers. This archeological wonder was found in 1974 at Xi'an.

The Chinese mobilized an epic-scale production, but the amount of detail revealed by the large frame—ten times the size of a standard frame—presented a difficult challenge to art director Qian Yun Xuan. Howells explains: "People can see that man standing in the fiftieth row back, so he has to be just as well dressed and made up as the guy in the front; in a 35-mm frame you can have him in running shoes in the back row and nobody will notice." To supply the actors and the thousands of extras with accurate costumes and props, the Xi'an Studio temporarily converted more than thirty-five factories from their normal output to production for the film. One factory spent a month weaving fabric for costumes, another needed a month to stamp the fabric with designs, while a third took a month to make shoes.

The wide-angle lens exaggerates camera motion, and sudden movements by actors can leave audiences reeling. Thus, the codirectors had to adopt a number of unusual cinematic techniques. Normal close-ups would produce a face four stories tall, so the filmmakers used medium shots instead. The Chinese actors, trained to make theatrical gestures, had to learn to moderate their movements for the large-screen format.

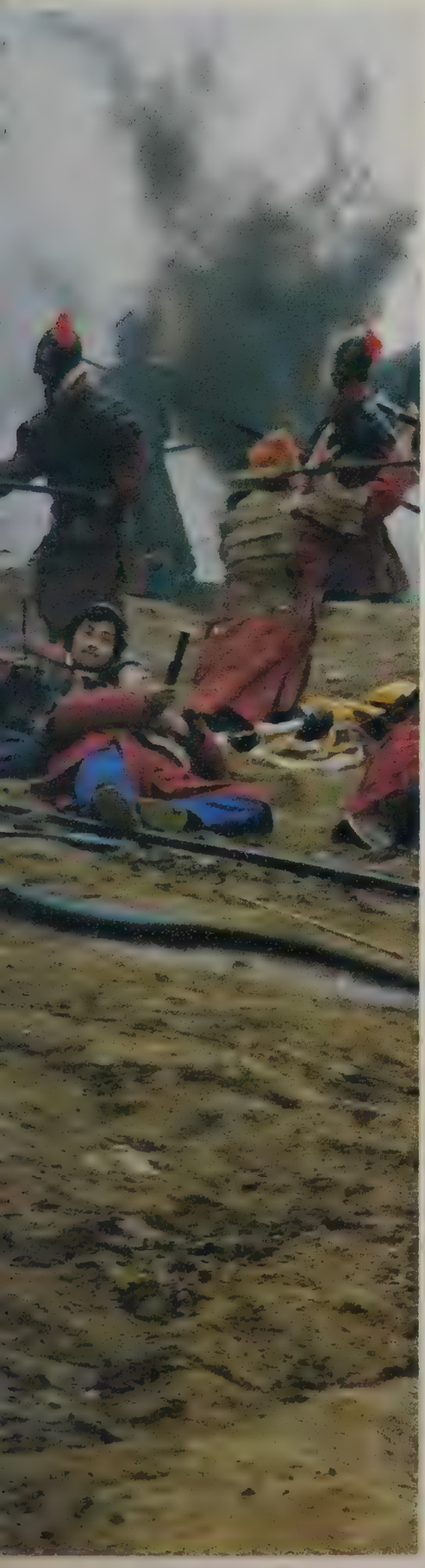
The First Emperor, produced at a cost of nearly $10 million, was the first production with a foreign partner for the Xi'an Studio. Although the Chinese had never worked on a film in the large-screen format, they had more experience than the Canadians with large-scale dramatic features. Chinese codirector Liu Hao Xue organized the large battle scenes. With two thousand soldiers marching in one direction over muddy terrain and horse-drawn chariots charging crosswise through the ranks, there was a constant danger from wheels breaking off or runaway horses. Every move had to be carefully choreographed. Largely through Liu's organizational skills, no actor was seriously injured.

Simultaneous sound recording is a crucial part of large-screen format productions, because the more than 200 soundtracks of the film help create the illusion of depth and action. The Chinese, however, were accustomed to what film-



For the coronation scene in the giant-screen film The First Emperor, *China Xi'an Studio built a seven-story concrete palace, cast a dozen 25-foot-high metal statues, and assembled 600 musicians.*

Two thousand People's Liberation Army soldiers were employed as extras in battle scenes, with kung fu specialists brought in for hand-to-hand combat.



makers call the Italian style—shooting silent footage and dubbing in the sound afterward. This difference in technique frustrated everyone. Achieving quiet on the set was nearly impossible—especially when large crowds from the surrounding countryside gathered to watch the production. The difficulty of placing microphones for synchronous sound often delayed the shooting of scenes—sometimes until the sun set on thousands of extras.

The technological demands of the project strained Chinese resources. Because of the camera's wide perspective, the indoor scenes required huge banks of bright lights. Cinematographer Susan Trow explains that while both crews shared the same basic ideas about lighting, the Xi'an Studio had never had to meet such massive power requirements. As a result, there were occasional power failures. When the production was running behind schedule during a gasoline shortage, the Xi'an Studio had to buy fuel on the black market to transport the army to the shooting location. Resources that Western producers take for granted were often scarce, but the Chinese found many inventive solutions to meet the Canadian filmmakers' needs. For example, the co-directors had a heated discussion about sandbags. The Canadians had erroneously assumed that any film studio would have sandbags to keep lighting stands from toppling over, but none were available. The Chinese simply assigned a crew member to hold up each stand.

Many of the misunderstandings that arose were eventually traced to problems of interpretation. Simple requests somehow became complicated in translation. Finding interpreters with a knowledge of the technical film vocabulary was particularly difficult. Associate producer Margaret Wong, a Canadian fluent in Chinese, was pressed into service as an interpreter. Interpreters, she says, are "human telephones; they are a tool whereby two parties can communicate with each other." According to Wong, "any kind of cultural exchange between two countries is supposed to accomplish a better understanding. Even though you are so different, if you have trust and good communication, you can do it."

Thomas R. Miller

AT THE AMERICAN MUSEUM

MOONSTRUCK

Twenty years ago this month, the world watched as human beings first walked on the moon. The Museum will commemorate this historic anniversary on Tuesday, July 18, with a lecture by former astronaut Michael Collins entitled "Men on the Moon: Twenty Years Later" at 7:30 P.M. in the Main Auditorium. In July 1969, Collins, a member of the *Apollo 11* crew, piloted the command module *Columbia* in lunar orbit while his colleagues, Neil Armstrong and Edwin "Buzz" Aldrin, explored the moon's surface. He will discuss their pioneering voyage, as well as plans for future space exploration, including a joint U. S.–Soviet manned mission to Mars scheduled for the year 2004.

The Hayden Planetarium will observe the occasion with jazz concerts at 7:00 and 9:00 P.M. on Thursday, July 13, in the Sky Theater. A group of outstanding musicians, led by bassist Milt Hinton, will perform lunar tunes, such as "Fly Me to the Moon" and "Moonglow," to the accompaniment of "moonbeams" and other visual effects.

Tickets for the concert are $12 for members and $15 for nonmembers; for more information, call (212) 769-5907. Tickets for the lecture are $10 for adult members, $8 for members' children, and $12 for nonmembers; for more information, call (212) 769-5606.

These events take place at the American Museum of Natural History, located on Central Park West at 79th Street in New York City. For more information about the Museum, call (212) 769-5100.

Square, Gassed Tomatoes and Othe

Exactly what makes the industrial tomato taste so blah?

by Raymond Sokolov

In a world riven by hate, greed, and envy, everyone loves tomatoes. I have never met anyone who didn't eat tomatoes with enthusiasm. Like ice cream, the whole, perfect, vine-ripened tomato is a universal favorite. The old-fashioned kind of tomato, not the hard-walled hybrids picked green, engineered to survive long truck rides, and ripened with gas on the way to market.

Real (as I will call vine-ripened, soft-walled, acid-flavored, summer-grown) tomatoes are an article of faith, a rallying point for the morally serious, a grail. And the real tomato's acolytes are not some ragged little band of malcontents. They are us, brothers and sisters in tomatomania, converts to the first Western religion since the Stone Age to worship a plant.

Everyone I know seems to have his own story of how the scales fell from his palate as he tasted, really tasted, a real tomato for the first time. My own ecstatic rebirth as a tomatomane took place on a rail siding in some border no man's land between Yugoslavia and Greece in early August of 1960. After two days of sparse and dismal food on the old Simplon-Orient Express passing through Yugoslavia, I was able to buy a large red tomato from a boy hawking them to passengers waiting on the platform. I bit into one; juice spurted on my cheeks and tears almost mixed in. I still quiver when I recall that moment.

Such pure memories, reinforced each summer by new experiences with real tomatoes, have their dark side. They make us picky, unwilling to settle, or at least to settle happily, for false tomatoes. And so we become tomato bores, railing against square tomatoes without taste.

The Tom Paine of this rebellion is Thomas Whiteside, who attempted to get to the bottom of the dark lagoon of tomato industrialization in an exhaustively reported article in *The New Yorker* in 1977. It was Whiteside who spread the word about tomatoes picked green for durability and transportability from Florida. It was Whiteside who alerted *New Yorker* sophisticates to the existence of square tomatoes, hybridized by modern plant scientists to accommodate mechanized harvesting. And it was Whiteside who raised the consciousness of upper-middle-class America about artificial ripening of tomatoes induced by ethylene gas.

Of course, there were other tomato muckrakers out there building the almost complete consensus of intelligent consumers against the supermarket tomato. But an informal survey indicates that Whiteside was the crucial figure, the tomato Jeremiah behind whom a growing throng collected. All praise to him. He pointed to a great truth: the industrial tomato is a dud. Only corporate executives of tomato companies would disagree with that.

In attempting to think clearly about this matter, it is crucial to keep in mind that the tomato we hate is the one that we buy whole and raw to be consumed whole and raw. We are not talking about tomatoes produced for canning. This means that the square tomato is a red herring. The square tomato is not a tomato you and I can normally buy. It is aimed at the commercial canning market, where delicacy of texture and taste is of far less moment than it is for fresh tomatoes. In any case, I have never laid eyes on a square tomato and I doubt most tomato radicals have. So the square tomato is an illegitimate rallying point. Yes, it exists, and Gordie C. Hanna, of the University of California at Davis, did engineer the first cultivar suitable for machine harvesting, the VF 145, in the 1950s and 1960s. But to set up the VF 145 as an outrageous example of the perversion of science in the service of agronomic pelf would be a distortion.

So is the hate campaign against artificial ripening. The gas that growers use, in storage areas and in trucks hurtling northward, to set the process of ripening in motion is the same gas that tomatoes and many other plants produce in the normal course of natural ripening. This gas is ethylene. According to *Webster's New World Dictionary,* it is "a colorless, flammable gaseous hydrocarbon of the olefin series . . . with a disagreeable odor: it is obtained from natural or coal gas, by cracking petroleum, by the action of sulfuric or phosphoric acid on alcohol, etc., and is used as a fuel and anesthetic, in hastening the ripening of fruits and to form polyethylene."

To the eye of the scientophobe, that

Aerial view of a tomato harvest

Modern Myths

definition settles the argument. What could be worse than to asphyxiate tomatoes with the same poison that comes from air-polluting petroleum, puts people out on operating tables, and contributes to the degradation of the environment in the form of nonbiodegradable and unnecessary plastic packaging?

Yes, but ethylene per se is a benign natural organic substance. A ripe apple exudes it into the air and will hasten the ripening of other fruits, including tomatoes. Not all chemicals are bad. It is the use we put them to that counts.

Yet there must be some explanation for those pale and tooth-resistant tomatoes. My theory was that a plant geneticist/villain had messed about with the genes of "normal" garden tomatoes and concocted a sturdier hybrid fit for long interstate trips in eighteen-wheeled tractor-trailers. That mad doctor of the plant labs deserved to be the target of a campaign of vilification as a traitor to his science and to humanity. I set out to find him.

Suspect No. 1 was the man who had hybridized Florida's infamous Walter tomato. The Walter won't ripen after picking until it has been gassed. And the Walter was the ancestor of the MH-1, a grower's dream developed by the University of Florida at Homestead. According to Whiteside, you could play catch with the MH-1 at twenty paces or let it fall from more than six feet without breaking the skin. The Walter and the MH-1 are not cannery tomatoes. They are for the table. They and tomatoes like them, from south Florida and from the state of Sinaloa in Mexico, are what make tomato lovers gnash their teeth and wish for a Senate select committee to expose the whole tasteless mess.

George D. Lepp; Bio-Tec Images

I was one of these people until I met Charles M. Rick, a retired professor of plant genetics at the University of California, Davis, known in his field as Mr. Tomato. Ruddy, lanky, white-haired, and white-bearded, Rick is a completely unabashed enthusiast for the achievements of tomato science as he has known it since his student days, which ended in 1940 with a Harvard doctorate.

Since then, he and his colleagues all over the world have capitalized on the extraordinary genetic malleability of the tomato to increase crop yields manyfold. Rick is not, however, an ethereal lab technician. Far from it. He is famous for trekking all over Peru in search of wild tomato strains that might enrich the gene pool of cultivated plants back home. He's a home gardener, too, and talks with enthusiasm about Burpee's Better Boy and another favorite variety, Caligrande, which he grows today because of its resistance to tobacco mosaic virus.

For the past six years, Rick has been assembling a tomato germ plasm bank, a collection of 2,600 to 2,700 tomato lines in the form of seeds. When I was there, two women in his lab were extracting seeds from wild green tomatoes the size of gooseberries. Andean plants like these have been the source of "virtually all tomato disease resistance since the forties," he says.

Although Rick is the epitome of the modern tomato scientist, he is also in the great tradition of untutored green thumbs who long ago hybridized the red, fist-sized

tomato we think of as normal from the tiny wild fruit nature gave to our pre-Columbian ancestors. By the time Cortés reached Mexico in 1519, cultivation had already produced tomatoes we would recognize today. Hybridization continued in Europe. All the garden tomatoes we love so much are the result of centuries of human meddling. Today's commercial varieties are no more artificial than the "normal" kind. And, if Rick is right, they are not categorically worse in quality.

"I don't think it's right to attribute poor market quality to breeding," he says. "That's a bunch of nonsense. Unbiased tests have been conducted—at Michigan State, for example—blind tastings of commercial varieties that were all vine-ripened. Most of the criticism is a reaction to what's happened to these tomatoes when they're grown in the off-season. The sad fact is that you can't grow a tomato on the west coast of Mexico in January, pick it green, ship it three to four thousand miles, and expect it to be as good as a garden fruit in summer. Ethylene ripening is not the issue; it's the season, the low light in winter that hurts. And they add a greater handicap by picking them green and ripening them in transit. . . . I'm not sure the best tomato in the world would be a gem under those conditions."

He saw some possible hope in work being done on tomato ripening at a Davis biotechnology firm, Calgene Inc., which just received a patent for an alteration of tomato DNA. The change affects the function of the enzyme that causes softening of the fruit during the ripening process. By thwarting the enzyme, Calgene has created a tomato that stays firm longer, while ripening normally in other respects. In principle, the Calgene tomato could be picked mature instead of green, after it had developed flavor.

These are early reports, and the most optimistic prediction for the first retail sales of these tomatoes is two winters from now. Field tests are currently under way in Mexico. But in the meantime, the pressure of a $4 billion U. S. market for fre tomatoes has finally convinced one bo and energetic New York family nam Marcelli to take a great leap forward. Th past winter, they were managing to deliv high-quality tomatoes to Manhattan re taurants and grocers. How do th Marcellis do what no one else seems ab to manage? Simple. They let Florida t matoes ripen on the vine. They truck the nonstop to New York. And they kee them cool, at 55 to 60 degrees, but don refrigerate, which would degrade flavor

"Real tomatoes," as the sticker on eac one reads, are not up to the supreme sta dard of summer garden fruit. And the are certainly expensive. But they sho that the real obstacle to bringing decen domestic tomatoes to U. S. tables in th off-season is human greed and lazines not bad science or gas.

Raymond Sokolov is a writer whose spe cial interests are the history and prepara tion of food.

Two Tomato Recipes Slightly Adapted from *Classic Indian Vegetarian and Grain Cooking,* by Julie Sahni (Morrow, 1985)

Khatti Bhaji (Sour Eggplant)

This Punjab specialty gets its sourness from the large quantity of tomato used to braise the eggplant. Garlic and mustard oil add distinctive flavor.

- 1 medium eggplant (about 1 pound), unpeeled
- ½ pound baking potatoes (about 2 large ones)
- 1 cup mustard oil
- ⅓ cup sliced garlic
- 2½ cups thinly sliced onions
- 4–8 hot green chilies, thickly shredded
- ½ teaspoon turmeric
- ½–1 teaspoon cayenne pepper
- 2½ cups thinly sliced tomatoes
- 1½ teaspoons coarse salt, or to taste

1. Cut the eggplant in half lengthwise (do not peel). Cut each half across into halves. Cut each quarter into slices about ⅜ inch thick. Scrub the potatoes clean under cold running water. Cut the potatoes in half lengthwise. Cut each half into long thin slices about ⅜ inch thick. Put the eggplant and potato slices in a large bowl of water and set aside.
2. Measure out the spices and place them right next to the stove in separate piles. Heat the mustard oil in a very large *kadhai,* the Indian version of a wok, or in a heavy, 5-quart skillet until very hot and smoking. Turn off the heat and let the oil cool for a few minutes. Heat the oil again over high heat. When it is very hot, add the garlic and cook, stirring and turning, for 2 minutes or until it begins to color.
3. Add the onion and continue cooking for 5 minutes. Add the chilies and cook for 2 minutes more. Add the turmeric and cayenne pepper and let it sizzle for 30 seconds.
4. Add the eggplant, mix the ingredients, and cook, turning the vegetables to distribute the spices and adjusting the heat as necessary, for 8 minutes or until the eggplant softens slightly and begins to fry. Add the potatoes and continue to cook, turning them, for 3 minutes. Add the tomatoes and the salt and reduce the heat to medium–high. Cook the vegetables, turning them constantly, for 10 minutes. Finally, reduce the heat to medium–low and let the vegetables fry undisturbed until they are soft.

Yield: 6 servings

Masala Bhindi (Braised Okra with Tomatoes and Spices)

In this recipe, too, the tomatoes are a means of adding sourness to the dish. (Indeed, for Indians, tomatoes tend to be linked with tamarind, lemon juice, and dried mango powder as a sour medium, Ms. Sahni writes.) But they also prevent the okra from turning slimy, as they otherwise will in contact with moisture.

- ½ cup vegetable oil
- 1 pound okra, topped and tailed
- 2 cups finely chopped onion
- 2 teaspoons minced garlic
- 2 tablespoons grated or crushed fresh ginger
- 2 teaspoons ground cumin
- 2 teaspoons ground coriander
- ½ teaspoon ground fennel
- ½ teaspoon cayenne pepper
- ¼ teaspoon turmeric
- 1½ cups finely chopped tomatoes
- 1½ teaspoons coarse salt, or to taste
- 3 tablespoons chopped fresh coriander

1. Heat ¼ cup of the oil in a large, heavy skillet over medium–high heat. When the oil is very hot, add the okra in a single layer and fry without stirring for 1 minute. Continue cooking for 3 or 4 minutes more, tossing and turning the okra until it is lightly browned. Remove the okra from the pan and set aside.
2. Measure out the spices and place them right next to the stove in separate piles. Add the remaining ¼ cup oil to the same pan along with the onion. Cook the onion until lightly golden (about 5 minutes). Add the garlic and ginger and cook, stirring constantly, until the mixture turns caramel brown (about 8 or 10 minutes).
3. Add the cumin, coriander, fennel, cayenne pepper, and turmeric. Stir for a few seconds, then add the tomatoes. Reduce the heat to medium and cook, stirring for 3 minutes or until mixture thickens and becomes pulpy. Add the fried okra, the salt, and 1 cup hot water. Stir and bring to a boil. Lower the heat and cook, covered, until the okra is cooked (about 20 minutes) and the sauce is thick. Stir in a little of the fresh coriander and garnish with what's left.

Yield: 4 servings

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PRAYER TO THE HEALING SPIRIT

Twilight Stars

by Thomas D. Nicholson

Mercury, Venus, Mars, and Jupiter are so close to the sun in the sky in July that they are either invisible or hard to see. But following the movements of these morning and evening "stars" is not impossible.

An evening star is a prominent planet visible after sunset, while a morning star is one seen before sunrise. Planets rising before the sun in the morning are to the sun's right along the ecliptic, and those left behind in the evening sky by the setting sun are to the sun's left. Their apparent distances from the sun can be approximated by when they rise or set relative to the sun.

In early July, Jupiter and the stars of Taurus are to the sun's right, but so close that the sun rises right behind, and the quickly brightening sky obscures them. During July, the sun drifts east (left) through the stars (reflecting the earth's revolution around the sun), so that by the end of the month, the sun is far enough away from Jupiter and Taurus that they rise much earlier, and Jupiter becomes a prominent morning star.

The story is different for Venus. During July it is so close to the left of the sun that it sets about one and a half hours after the sun for the entire month. In the evening twilight, Venus' great brilliance will enable us to see it low in the west–northwest for a half hour after sunset.

While Venus is in the process of entering the evening sky this month, Mars will be leaving it. Much fainter than last fall, this ruddy evening star sets about one and three-quarter hours after sunset at the beginning of July, but less than an hour after at month's end.

Finally, Mercury swings past the far side of the sun on the 18th as it moves from the morning to the evening sky. Thus it will be a morning star for just over half of July and an evening star for the remainder of the month. Its proximity to the solar glare, however, will make it virtually impossible to see.

Events in the calendar occur in local time unless otherwise indicated.

July 1: Mercury and Jupiter are very close to each other low in the predawn sky, rising some one and a quarter hours before the sun. The thin morning crescent moon is above them.

July 2: Saturn, at opposition (directly behind the earth) from the sun, shares the sky with both evening and morning stars. Rising at sundown and setting at sunrise, it makes its evening star debut in Sagittarius. New moon (between the sun and the earth) is at 11:59 P.M., EST.

July 4–5: The earth reaches aphelion, its farthest distance from the sun (94.5 million miles), on the 4th. The young evening crescent moon passes close to Venus at 11:00 P.M., EST, on the 4th and close to Mars at 7:00 A.M. on the 5th. The moon occults Venus in the Far East at their conjunction. Venus is visible just above the moon, but Mars is too faint to be seen with the unaided eye in the twilight glow.

July 6: Tonight's young moon is well up in the sky after dark, to the left of Leo's bright star Regulus, which the moon will occult over the South Pacific.

July 8–10: The moon waxes as it approaches first quarter, appearing higher and staying up later each night. Moving into Virgo on the 8th, the moon reaches apogee (farthest from the earth) on the 10th, passing Spica late at night after reaching first quarter at 7:19 P.M., EST.

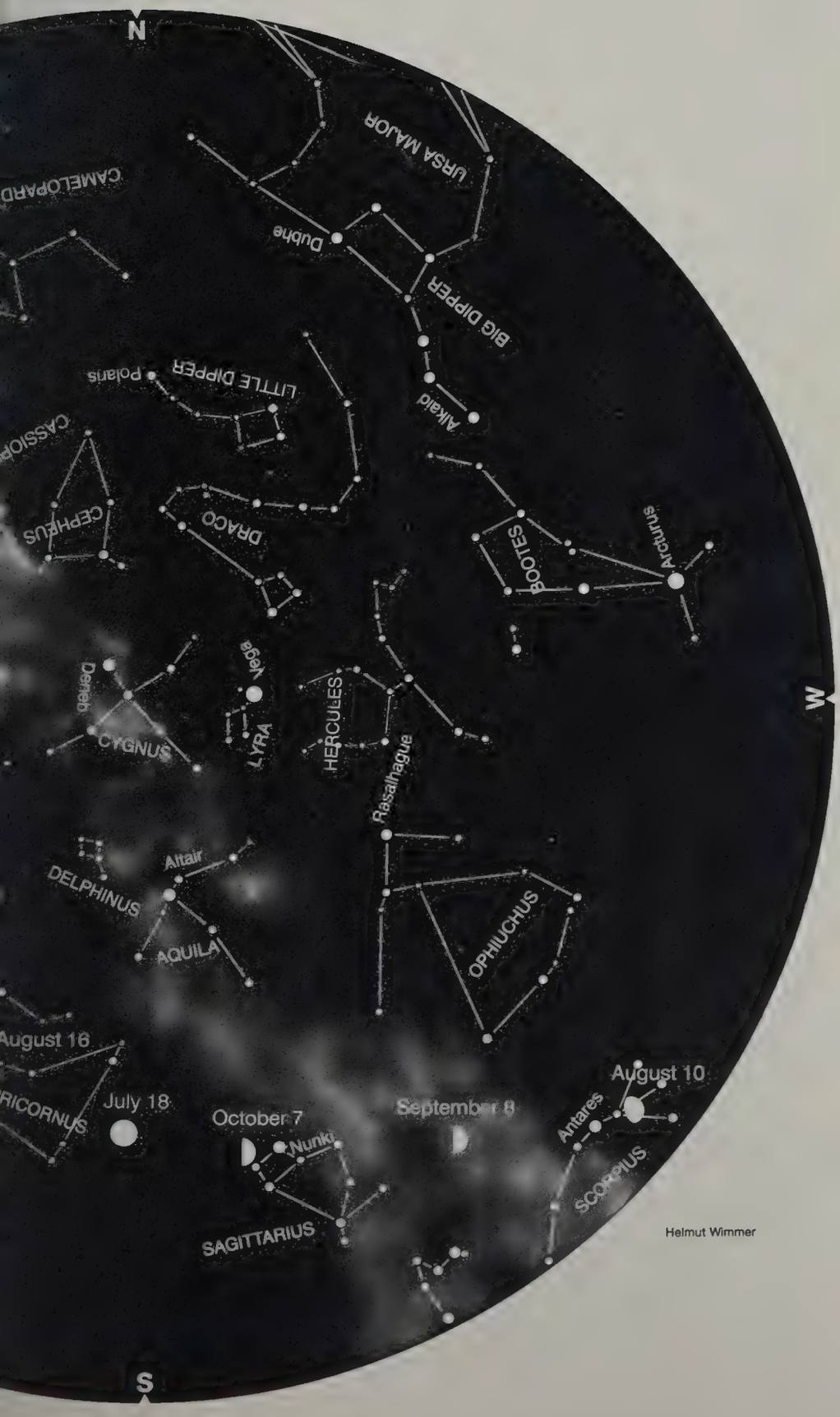
July 12: Venus and Mars are half a degree apart, low in the evening sky. Venus is very bright, and Mars (just below it) is dim and redder. The gibbous moon waxes as it moves through Libra.

July 14: The moon passes just below Scorpius' bright reddish star, Antares, occulting it in the Southern Hemisphere at about midnight.

July 17: The moon passes beneath Saturn at 7:00 A.M., EST, while in Sagittarius' Teapot. The planet, at its brightest for the year, can be easily seen through the moonglow.

July 18: Full moon, at 12:42 P.M., EST, moves into Capricornus late at night.

July 22–23: Now rising well after sun-



Helmut Wimmer

down and remaining in the sky past dawn, the waning gibbous moon is in Pisces and reaches perigee (nearest the earth) at 2:00 A.M., EST, on the 23d.

July 25: Last-quarter moon is at 8:31 A.M., EST, shortly after it enters Aries. The Ram's bright stars, Hamal and Sheratan, are nearby.

July 27: After the crescent moon rises this morning, look for the Pleiades cluster (the Seven Sisters) to its right and for the reddish star Aldebaran (in the V-shaped Hyades cluster) well below it. The stars belong to Taurus, prominent during winter nights.

July 28: The weak Delta Aquarid meteor shower (twenty or so shower meteors per hour at best) reaches maximum.

July 29–30: If you haven't seen Jupiter in the morning sky yet, use the crescent moon to guide you: Jupiter is the bright object to the moon's lower right just before dawn.

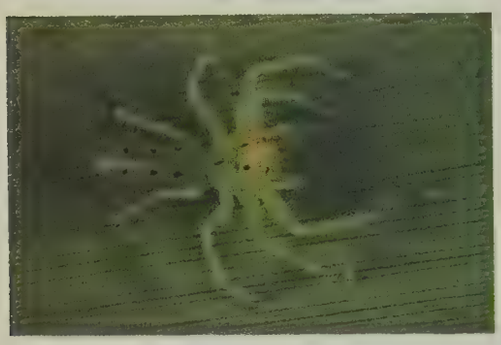
July 31: New moon is only a day away, so the night sky is dark and moonless.

The summer Sky Map shows the sky for July, August, and September from 40° north latitude at the hours given below. To use the map, hold it vertically in front of you with south (S) at the bottom and match the lower half with the stars you see when you face south. As you face in other directions, turn the map to bring the corresponding compass direction to the bottom. The stars move continuously westward during the night. By morning (before dawn), those on the western half of the map will have set, those on the eastern half will have moved into the west, and new stars (those of the fall evenings) will have risen in the east. The map represents the sky at about 1:30 A.M. on July 1; 12:30 A.M. on July 15; 11:30 P.M. on August 1; 10:30 P.M. on August 15; 9:30 P.M. on September 1; 8:30 P.M. on September 15; and 7:30 P.M. on September 30. Add one hour for daylight time. The map can be used for an hour or more before and after the times given.

If Looks Could Kill . . .

Poised on a leaf, a tiny Florida jumping spider gazes into the camera lens just long enough to be captured on film. For its prey, the stare is equally brief. Within a fraction of a second, the spider can spring forward on its hind legs and impale an unfortunate insect with its fangs.

Although most spiders have eight eyes, their vision is a poorly developed sense; as they wait to trap insects in webs or on the ground, tactile and chemical cues are more important. Jumping spiders, however, have evolved a complex visual system that is ideally suited to their habit of stalking prey. Of their eight eyes, the six small ones (two are visible here) on the sides of the head cannot distinguish



details but are very good at detecting motion. The spider uses these eyes to spot movements a little more than a foot away. Should an insect (or a finger) approach much closer than this, the spider turns with a quick jerk to face it with its two large eyes. More highly developed, the pair of large eyes can focus on fine details, but only within a few inches and only in a very narrow field of vision. (This problem is partly overcome by special muscles that move the retinas in the back of the eyeballs, allowing the spider to "scan" an entire object and distinguish among prey, predators, and mates.) Once a meal is identified, the jumping spider stealthily approaches to within an inch or so of the victim and then pounces.—*R. A.*

Actual size of *Lyssomanes viridis*

Photographs by Tom Eisner

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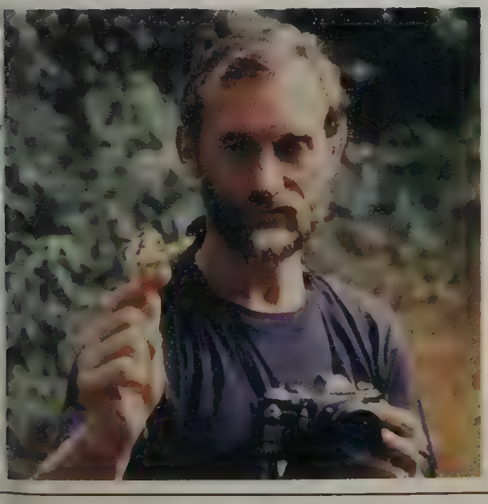
Authors

British-born naturalist **Ian J. Stran** (page 26) has been photographin painting, and writing about the wildli of his adopted home, the Falkland lands, for twenty-five years. He advis the government on environmental issu and as a Crown Agent Stamp Design has more than one hundred stamp illu trations to his credit. In 1988 Strange e tablished the New Island Conservati Foundation and set aside New Isla South, which he owns, as a wildlife r serve and site of a planned field statio The most recent of his six books, a fie guide to Falkland Islands wildlife, w be published in England later this ye by Collins. Black-browed albatrosses a featured in his photo-illustrated boo *Guide to the Falkland Islands a Their Natural History* (New York: Hi pocrene, 1987).

Gary A. Polis's introduction to scorpions came in his first year of graduate study, sixteen years ago, and he says he immediately recognized their potential as model organisms for studying a variety of ecological and evolutionary questions. Now an associate professor at Vanderbilt University, Polis (page 34) has stuck with them ever since, and he has never been stung by a truly dangerous scorpion (five times by "innocuous species that don't really hurt too much"). In addition to his research in the Coachella Valley in California's Riverside County, Polis has tracked scorpions in southern Australia, the Namib Desert of southwestern Africa, and Baja California. Ongoing projects include a study of the biogeography of spiders and scorpions on the islands off Baja California, in the Sea of Cortés, and the ecological genetics of scorpion species with different population structures. Polis recently edited *The Biology of Scorpions,* which will be published next month by the Stanford University Press. Another source of information about desert creatures is G. N. Louw and M. K. Seely's *Ecology of Desert Organisms* (New York: John Wiley and Sons, Inc., 1982).

Inspired by a pet that came with the cottage where he lives, **Peter B. Churcher** (page 40) investigated cat predation for a master's degree in biology and education from York University in England. Churcher, above, is head of biology at Bedford School, a public school for boys. Coauthor **John H. Lawton**, below, is director of the Centre for Population Biology and professor of community ecology at the Imperial College of Science, Technology and Medicine, University of London. His present research includes insect–plant interactions. For additional reading see "Urban Cat Populations Compared by Season, Subhabitat and Supplemental Feeding," by R.E. Calhoon and C. Haspel (*Journal of Animal Ecology*, 1989, vol. 58, pp. 321–28), and *Wild Life of the Domestic Cat*, by Roger Tabor (London: Arrow Books, 1983).



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In 1985, when **Carl Gans** (page 48) arrived at the National Museum of Natural History in Paris to take up an appointment as guest professor of comparative anatomy, he was struck by both "the sad state of the Grande Galerie and Mr. Kreienbühl's spectacular paintings documenting the need for recovery." Back home at his University of Michigan post as professor of biology, Gans (portrayed above in a Kreienbühl painting) studies the evolution of vertebrates, the functional morphology of burrowing animals, and "the way muscles work." Born in Hamburg, Gans emigrated to the United States before World War II. Trained as a mechanical engineer, he spent ten years in the profession, but a longstanding interest in natural history eventually led to a doctorate in biology. His fascination with biomechanics combines the two fields. Committed to studying animals outside the confines of laboratories and museums (because "you have to see and handle animals before you can understand them"), Gans has worked in the field on all the continents except Antarctica. For a sense of the history of French zoology, he recommends Toby A. Appel's *The Cuvier-Geoffroy Debate: French Biology in the Decades Before Darwin* (New York: Oxford University Press, 1987). **Jürg Kreienbühl** was born in Basel, Switzerland, but for more than twenty years has made his home in Cormeilles-en-Parisis, just outside of Paris. Like the late American artist Edward Hopper, Kreienbühl usually paints subjects traditionally considered unworthy of artistic attention; much of his work reveals his preoccupation with the effect of the spreading city on the landscape and inhabitants of the poorer Paris suburbs. In the late 1970s, Leonard Ginsburg, director of paleontology at the National Museum of Natural History, introduced Kreienbühl to the Grande Galerie de Zoologie. In the words of one of his friends, Kreienbühl's "compulsion to revive bizarre, forgotten, or submerged worlds" responded. The result was a major exhibition, "Jardin des Plantes," sponsored by the museum in 1985. Kreienbühl is now contemplating a series of paintings of nuclear plants.

While **Tom Eisner** (page 76) was observing a jumping spider through the eyepiece of a camera-equipped microscope, it turned to face him, and he snapped its portrait. The tiny subject of this month's "Natural Moment" was spotted by Robert Piel, a student and spider enthusiast who accompanied Eisner in the field at the Archbold Biological Station, a research center near Lake Placid, Florida. Eisner is the Schurman Professor of Biology at Cornell University, specializing in entomology. For further information about jumping spider vision, one can read "Vision and Prey-catching Strategies in Jumping Spiders," by Lyn Forster (*American Scientist*, March-April, 1982), and *Biology of Spiders*, by Rainer Foelix (Cambridge: Harvard University Press, 1982).

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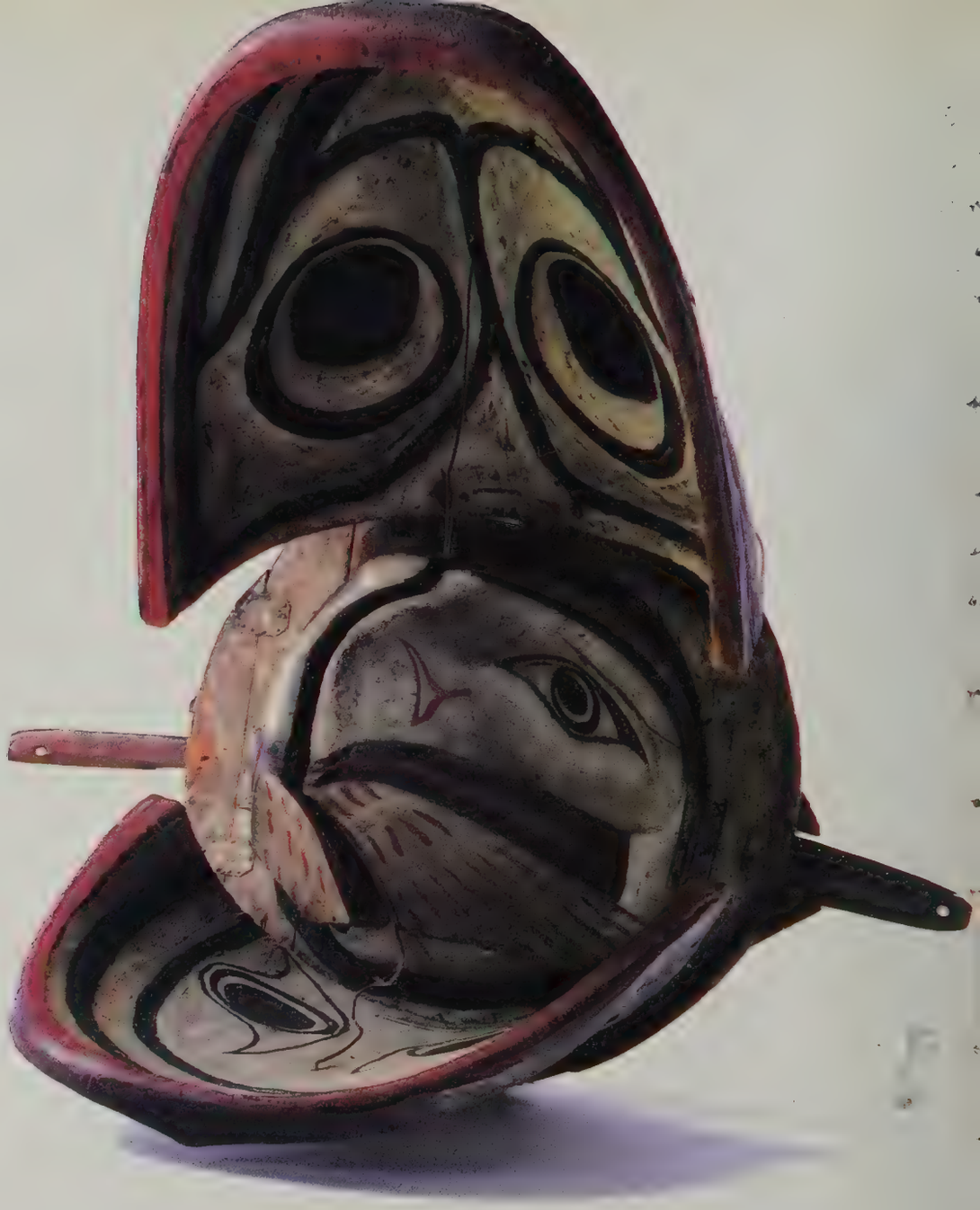
From the Land of the Totem Poles



The Northwest Coast Indian Art Collection at the American Museum of Natural History

by Aldona Jonaitis

Less than a century ago, the Indian tribes living along the Northwest Coast of North America were under great pressure to forsake their cultural heritage. At stake were their religious practices, their mythology and customs, and their ancient way of life.

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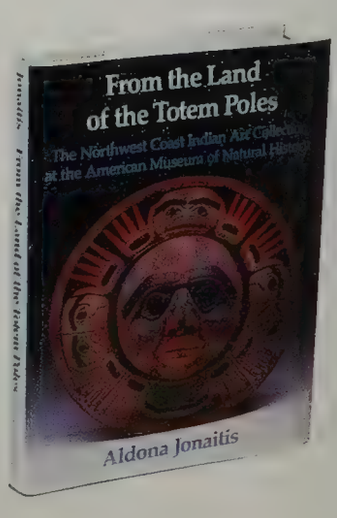

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NATURAL HISTORY

AUGUST 1989

COVER: *In a burned-over section of Yellowstone National Park, a young elk grazes on the lush spring grasses of the ash-fertilized land. The healthy animal, one of many that survived last summer's holocaust, is shedding its winter coat. Stories on page 34. Photograph by Michael S. Quinton.*

4 LETTERS

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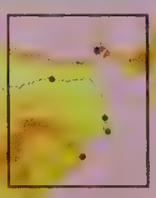

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Complete rules and entry forms will be published in *Natural History* when we get closer to the deadline.

LETTERS

BEASTS OF BATTLE

A few days ago I picked up the February 1989 issue of *Natural History* and read the interesting essay on raven behavior. What caught my attention was the ravens' yelling to communicate and gather other ravens to a kill, and the anecdote about a raven leading a hunter (predator) to prey in the apparent expectation that it could then share in the food. Since my field is medieval English literature, I was immediately struck by the apparent similarity with an Old English poetic convention known as the "Beasts of Battle," in which the raven calls to the wolf (and sometimes the eagle too) to come share the corpses after a battle. There are examples of this poetic motif in *Beowulf*, *The Battle of Brunanburh*, and other epic poems from the eighth and ninth centuries. Could this ancient oral convention reflect actual observations of raven behavior, dating back to a time when the Germanic tribes, including the Saxons, were hunters living in a densely forested Europe?

MARY CARRUTHERS
University of Illinois at Chicago
Chicago, Illinois

IN DEFENSE OF BLACK OLIVES

I have just read Raymond Sokolov's April 1989 article on "The Thoroughly Modern Olive," with the appropriate and accurate subtitle: "Technology has produced a black olive to suit public tastes."

The writer then plunges headlong into the denigration of our industry and our company. The subhead is correct: the black, ripe olive does suit public taste, and I don't think that this makes our product unworthy per se or somehow flawed.

To suggest that the key to olive quality seems to be "the open vat" is presumptive, unsupported by the facts of public preference, and without regard to qualitative differences in the fruits used, environmental controls in the country of origin, or the reasons for producing the product in the first place. The California black, ripe-style olive sells more olives to more consumers in the United States than do all of the importing countries in all of their import styles. Among these are those sold in open vats. On a chart, open-vat olives wouldn't make a blip, but they do offer a wonderful, different taste to those few who prefer that timeless, sour, bitter edge of the Mediterranean style.

I wish we had recognized Mr. Sokolov's bias when he was here. We could have pitted it in a millisecond.

R. D. ROSSIO
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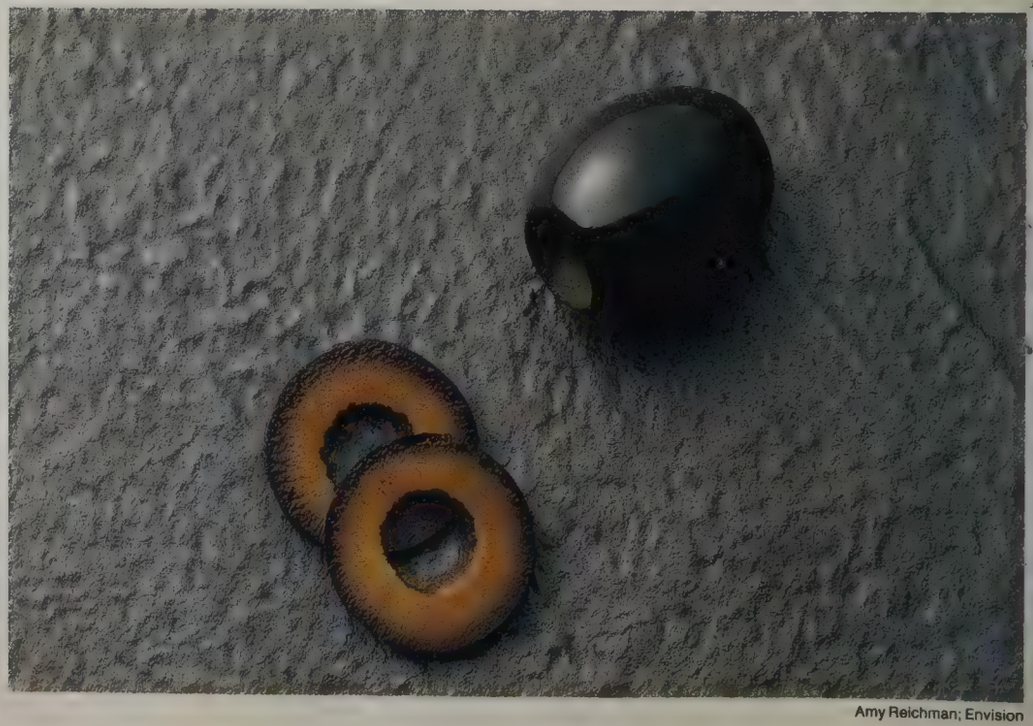

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The Wood Turtle Stomp

These woodland reptiles know how to drum up a meal

by John H. Kaufmann

I followed carefully behind the female wood turtle as she picked her way through the lush growth of tussock grass. After every few steps forward she would pause and rock from side to side, take another couple of steps forward, then repeat what appeared to be a tipsy stagger. My immediate thought was that she was suffering from some ailment that was affecting her sense of balance. Before long, however, she disappeared into the tall grass, leaving me uneasy over the possibility that one of the three turtles I had equipped with a radio transmitter might be dying.

This was in June of 1984, when I had just begun a study of the movements and social behavior of wood turtles, *Clemmys insculpta,* in the valley and ridge region of central Pennsylvania. In the freshwater turtle family, the omnivorous wood turtle spends more time wandering on land than any other species except the box turtle. Wood turtles live in forests from Virginia north to Nova Scotia and west to Wisconsin. They have long been regarded as special among North American turtles because they home accurately over unfamiliar terrain and are unusually active for reptiles in cold weather. Although th usually hibernate in the bottom mud creeks or ponds during the coldest month wood turtles have been seen moving abo in every month of the year, sometimes the snow or under the ice of ponds. reputation for extraordinary intelligen has made them popular as pets, leading a sharp decline in numbers because overcollecting by unscrupulous deale What attracted me to them was specul tion, based on observations of males figh ing, that they might defend territorie Such behavior was unknown among tu

An opportunist, the wood turtle consumes a wide variety of plants and animals.

Ted Le

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tles, and the chance to answer this question converted me to turtle watching after twenty-six years of studying mammals. (The turtles turned out to be nonterritorial, but the males do establish a hierarchy among themselves.)

A few days after observing the "tipsy" female, I came upon an adult male. When I first saw him he was sitting quietly beside a creek, but he soon wandered into a damp thicket of alder, spicebush, and false hellebore. Before disappearing from sight, however, he began to rock back and forth. I followed, trying to stay just close enough to see what he was up to without disturbing him. Fortunately, he did not scare easily, which allowed me to approach within a few yards as he meandered, walking and rocking. First, I noticed that the rocking was caused by short bouts of stomping with the front feet, alternating between left and right. Then he suddenly jabbed his head at the ground and ate something. This behavior continued for a half hour, and several times I caught a glimpse of the prey—earthworms snatched from the surface. I suddenly realized the turtle was "grunting" for worms!

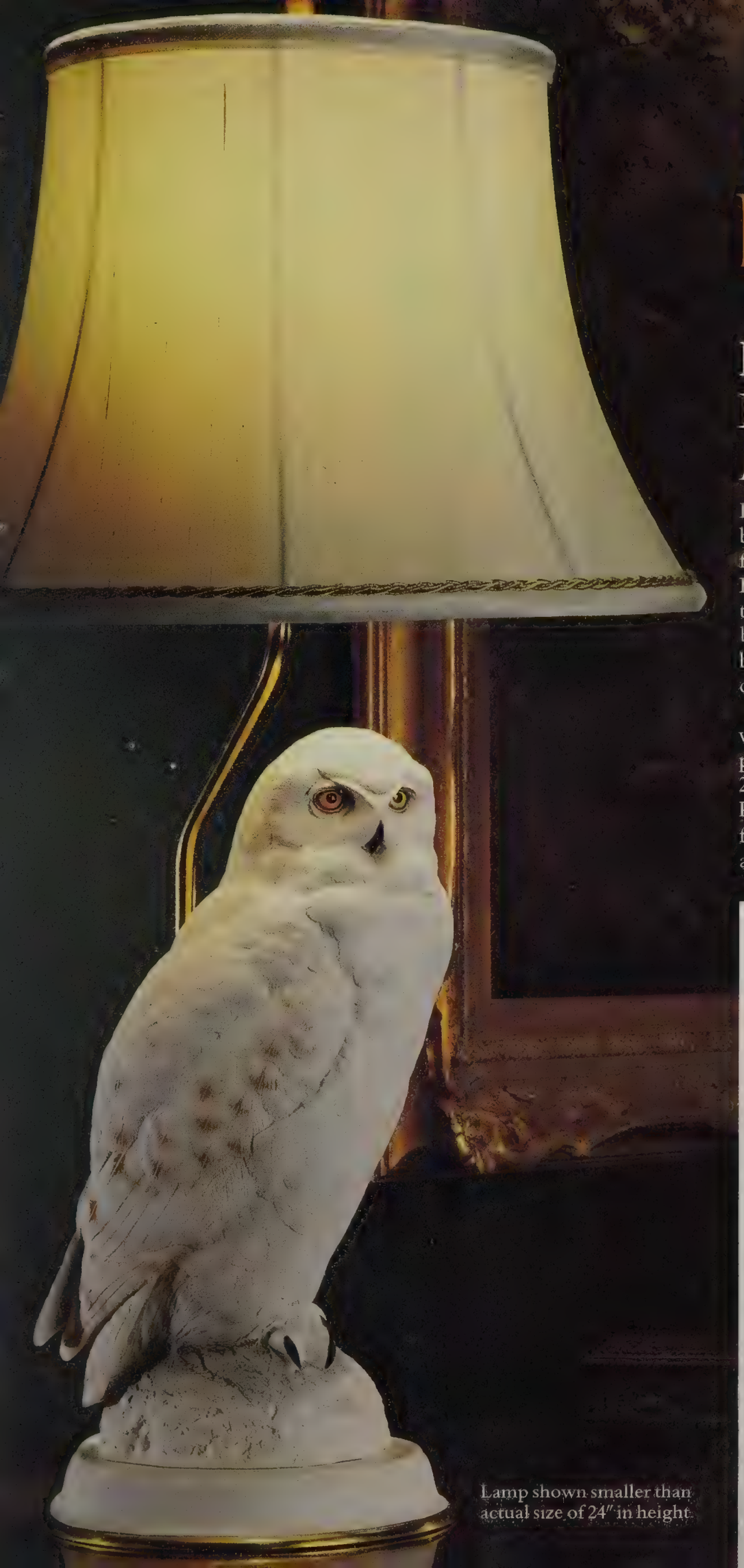
In northern Florida, where I teach, worm grunting is an effective and profitable means of gathering earthworms for fish bait. The worm grunter drives a wooden stake into the ground and rasps against it with a notched stick or a coil spring from an old car. Earthworms quickly emerge from the ground and wriggle across the surface away from the source of vibration. Many people catch worms for their own use, some supplement their income by selling worms to bait dealers, and a few make their entire living this way. The U. S. Forest Service allows controlled worm grunting on national forest lands, and about 700 people pay thirty dollars annually for permits to grunt for worms in the Apalachicola National Forest in Florida's panhandle. An annual worm grunting championship is even held in Florida, in which two-people teams compete to see who can catch the most worms in a given time. One member of the team rasps on the stake, while the other scurries around picking up the emerging earthworms within a circle marked on the ground. The worms appear to respond to just about any kind of vibration in the soil. Paul Moler, a biologist with the Florida Game and Freshwater Fish Commission, told me of a conversation he had with a woman who reported that worms surfaced around a power mower she had left running in the yard, and that another time they popped up around the feet of her daughters who were practicing their cheerleading routines in the yard.

Still, there is a big difference in the magnitude of vibrations produced by human worm grunters and those that can be produced by turtles weighing about two pounds. I began to pay close attention to stomping turtles in order to prove or disprove my conclusion. I saw the behavior again on 10 occasions in the next two months, and during the last four years I have seen it another 227 times. But I was not really convinced until I successfully imitated turtle stomping by tapping on the soil with two fingers, mimicking the force and rhythm used by the turtles. I caused six worms to surface from a one-foot-square area of bare streamside mud within thirty-five minutes; four of them within fifteen seconds.

A worm-seeking turtle usually stomps about eight times in eight seconds with one foot, gradually increasing the force of the stomp. Then it switches to the other foot. After a couple of bouts with each front foot it takes a couple of steps forward, pauses, and stomps again. The worm usually surfaces within a few inches of the turtle's feet and hurries off across the soil and leaf litter. The turtle snaps it up in its jaws and eats it. This happens even when the worm surfaces behind the turtle, and when two worms emerge simultaneously, both are usually caught. I have seen one turtle catch as many as seven

Gilbert van Ryckevorsel/Valan Photos

This wood turtle rests on a river bottom, its habitat during the cooler months.



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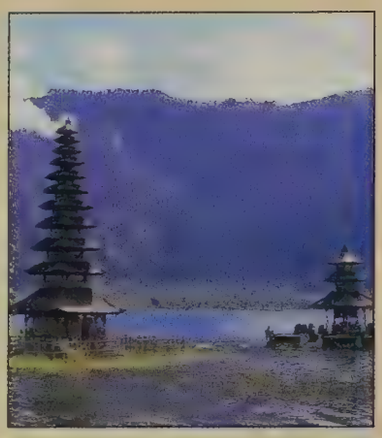

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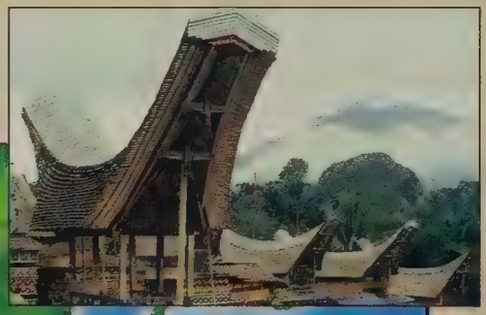

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worms in eight minutes, and another catch fifteen in one hour. The latter was one of four turtles stomping simultaneously along a fifty-foot strip of stream bank, evidently a good stomping ground. Sometimes, however, turtles stomp for a half hour or more without success.

Most sessions last from a half hour to an hour or two, but can last anywhere from a minute or two to more than seven hours (the longer sessions are usually interrupted by rest periods). In my study area, the behavior occurred every month from April through September, usually within fifty yards of a creek, except for several sessions that took place in hemlock swamps. The turtles use bare mud, alder thickets, forested stream banks, and grassy swales if the soil is damp. Rain seems to stimulate worm stomping, and 58 percent of the time I observed this behavior within one day of a rain shower. Worm stomping seems to be practiced by all of the adults in my study population.

When I made a quick search of the scientific literature, I turned up no mention of worm stomping by turtles of any kind, and when I first submitted my observations to a scientific journal, several veteran turtle biologists expressed considerable skepticism about my interpretation. One suggested that the turtles may have been trying to shake parasites off their legs, and another recommended that my observations be published, but without any mention of earthworms. Although I was convinced that I was correct, several important questions remained unanswered: How widespread is the behavior, at what age does it appear, and is it innate or learned from other individuals?

Finally, I heard from James Harding, a biologist at Michigan State University, who has been studying wood turtles in Michigan for two decades. He mentioned that Donald Zeiller, a dedicated turtle watcher, had described turtle stomping in a single paragraph in a 1969 article on the behavior of captive box turtles. Zeiller had watched a wood turtle (which happened to be among his captive box turtles) catch eight worms in twenty minutes in his backyard "turtle sanctuary" in New Jersey. More importantly, Harding reported that he had seen stomping motions made on a tiled floor by captive wood turtles in their first year. Moreover, these turtles had been hatched in captivity and isolated from older turtles. Then Kevin Brewster, who studies wood turtles at the Northwoods Wildlife Center in Wisconsin, reported stomping behavior by one of his captives. Thus, stomping behavior is widespread and appears as early as the first year, before it is learned from other tur-

tles. Actual worm capture, however, has been confirmed only in New Jersey by Zeiller and in Pennsylvania by me and my field assistant, Lori Smith, and subsequently on visits by James Harding and Kevin and Cathy Brewster.

Harding and I have also seen brief stomping motions made by wood turtles while courting and fighting. We have interpreted these as instances of out-of-context excitement or displacement behavior.

While we have clearly established that wood turtles cause earthworms to surface by producing vibrations in the soil, some people have questioned the relative importance of stomping alone versus the resultant thumping of the turtle's plastron (the hard plates covering its underside) against the ground. Sometimes the turtle simply rocks gently from side to side as it stomps, but usually the lower shell thumps against the ground during the last few, most energetic stomps, especially if the ground is uneven or stony. This thumping of the plastron can sometimes be heard for several yards. Three lines of evidence show that stomping alone can be effective, however, and offer hints as to how this remarkable behavior may have evolved.

First, famed Dutch ethologist Niko Tinbergen reported in *The Herring Gull's World* that gulls and plovers in Europe catch earthworms in damp meadows by tramping rapidly with both feet alternately or by vibrating one foot against the ground. In addition, there are hearsay reports that New Zealand kiwis may also stomp for worms. Clearly all of these birds are producing soil vibrations with their feet alone. Second, there was no equivalent to plastral thumping when I successfully mimicked wood turtle stomping with my fingers. Finally, when a wood turtle walked across a muddy bank as he left the creek, I saw a worm pop out almost beneath his feet and become a meal within seconds. The turtle was not stomping, and his plastron did not touch the ground. Apparently, worms near the surface may be stimulated to emerge by even the faint vibrations caused by normal walking. Increasing the force by stomping would increase the effectiveness of this stimulus, and plastral thumping caused by exaggerated foot movements would further magnify the effect.

Without a worm's-eye view of the world, we can never be certain as to why vibrations in the soil cause earthworms to emerge and flee across the surface. A popular explanation among Florida worm grunters is that worms mistake the vibrations for those caused by rain and emerge to avoid drowning. Tinbergen suggested that the vibrations caused by the gulls' tramping might mimic those caused by moles moving through their underground tunnels. Moles, enthusiastic worm predators, are common in the damp habitats where wood turtles stomp for worms. An observation related to me by Paul Andreadis, a graduate student at the University of Florida, suggests that Tinbergen may have been right. Andreadis was trying to capture a mole that was tunneling across his lawn. He jabbed a spade into the earth just ahead of the ridge formed by the mole as it plowed forward beneath the surface. The mole turned, sensing an obstacle, or perhaps danger, and ran toward the opposite end of the tunnel. As the mole was retreating, an earthworm popped up from the edge of the mole ridge (perhaps detecting vibration from the mole) and hurried off across the lawn away from the tunnel. Whatever its explanation, this response by earthworms has been exploited by several kinds of animals to improve their foraging efficiency.

John H. Kaufmann is a professor in the Department of Zoology at the University of Florida, Gainesville.

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The Dinosaur Rip-off

Yet the popular "craze has generated, amidst a supersaurus-sized pile of kitsch and crap, a remarkable range of worthy material"

by Stephen Jay Gould

We love occasional reversals of established order, both to defuse the tension of inequity and to infuse a bit of variety into our lives. Consider the medieval feast of fools (where slaves could be masters, in jest and only for a moment), Sadie Hawkins Day, and the genre of quiz that supplies the answer and asks a contestant to reconstruct the question. I begin this essay in such a spirit by giving my answer to a question that has surpassed all others (except, perhaps, "where is human evolution going?") in my catalog of inquiries from people who love natural history. My answer, unfortunately, must be: "Damned if I know"—which won't help you much in trying to guess the question. So I'll reveal the question without further ado: "What's behind the great dinosaur mania that's been sweeping the country during the past few years?"

Readers will scarcely need my words to document the phenomenon, for we are all surrounded by dinosaur tote bags, lunch boxes, pens and pencils, ties, and T-shirts that say "bossosaurus" or "secretaryosaurus," as the case may be. You can buy dinosaur egg soap to encourage your kids to take a bath, a rocking stegosaurus for indoor recreation (a mere 800 bucks from F.A.O. Schwarz), a brontosaurus bank to encourage thrift, or a dinosaur growth chart to hang on the wall and measure your tyke's progress toward the N.B.A. In Key West, where dinosaurs have even edged out flamingos as icons of kitsch, I even saw dinosaur toilet paper with a different creature on each perforated segment—providing quite a sense of power, I suppose, when used for its customary purpose. (This last reminds me of the best attempt I ever encountered for defusing the Irish situation. I once stayed in a small motel in Eire where the bathrooms had two rolls of toilet paper—one green, the other orange.)

I offer no definitive answer to the cause of this mania, but I can at least document a fact strongly relevant to the solution. Perhaps dinosaur mania is intrinsic and endemic, a necessary and permanent fact of life (once the fossils had been discovered and properly characterized); perhaps dinosaurs act as the trigger for a deep Jungian archetype of the soul; perhaps they rank as incarnations of primal fears and fascinations, programmed into our brains as the dragons of Eden. We can set aside these lurid conjectures for the simple reason that dinosaurs have been well documented throughout our century, while few people granted them more than passing notice before the recent craze hit.

I can testify to the previous status of dinosaurs among the arcana of our culture, for I was a kiddie dinosaur nut in the late 1940s when nobody gave a damn. I fell in love with the great skeletons at the American Museum of Natural History and then, with all the passion of youth, sought collateral material with thoroughness and avidity. I would pounce on any reinforcement of my greatest interest—a Sinclair oil logo or a hokey concrete tyrannosaur bestriding hole 15 at the local miniature golf course like a colossus. There sure wasn't much to find—a few overpriced brass figures and a book or two by Roy Chapman Andrews and Ned Colbert, all hard to get anywhere outside the Museum shop. Representations in pop culture were equally scarce, ranging little beyond King Kong versus the pteranodon and Alley Oop riding a brontosaurus.

One story will indicate both the frustration of a young adept in a world of ignorance and the depth of that ignorance itself. At age nine or so, in the Catskills at one of those innumerable summer camps with an Indian name, I got into a furious argument with a bunkmate over the old issue of whether humans and dinosaurs ever inhabited the earth together. We agreed—bad, bad mistake—to abide by the judgment of the first adult claiming to know the answer, and we bet the camp currency, a chocolate bar, on the outcome. We asked all the counselors and staff, but none had ever heard of a brontosaurus. At parents' weekend, his came and mine didn't. We asked his father, who assured us that of course dinosaurs and people lived together; just look at Alley Oop. I paid—and seethed—and still seethe. This could not happen today. Anyone—a few "scientific creationists" excepted—would both know the answer and give you the latest rundown on theories for the extinction of dinosaurs.

All this I tell for humor, but a part of the story isn't so funny. Kiddie culture can be cruel and fiercely anti-intellectual. I survived because I wasn't hopeless at punchball, and I won some respect for my knowledge of baseball stats. But any kid with a passionate interest in science was a wonk, a square, a dweeb, a doofus, or a geek (I don't remember what word held sway at the time, but one item in that particular litany of cruelty is always in vogue). I was taunted by many classmates as peculiar. I was called "fossil face" on the playground. It hurt.

I once asked my colleague Shep White, a leading child psychologist, why kids were so interested in dinosaurs. He gave an answer both elegant and succinct: "big, fierce, and extinct." I love this response, but it can't resolve the question that

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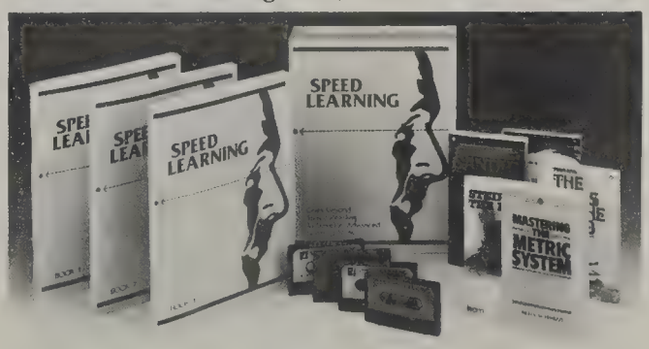

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prompted this essay. Dinosaurs were also big, fierce, and extinct twenty years ago, but few kids or adults were particularly interested. And so I return to the original question: What started the current dinosaur craze?

The optimistic answer for any intellectual must be that public taste follows scientific discovery. The past twenty years have been a heyday for new findings and fundamental revisions in our view of dinosaurs. The drab, lumbering, slow-witted, inefficient beasts of old interpretations have been replaced with smooth, sleek, colorful, well-oiled, and at least adequately intelligent revised versions. The changes have been most significant in three subjects: anatomy, behavior, and extinction. All three have provided a more congenial and more interesting perspective on dinosaurs. For anatomy, a herd of brontosauruses charging through the desert inspires more awe than a few behemoths so encumbered by their own weight that they must live in ponds. For behavior, the images of the newly christened *Maiasauria*, the good mother lizard, brooding her young, or a herd of migrating ornithopods, with vulnerable juveniles in the center and strong adults at the peripheries, inspire more sympathy than a dumb stegosaur laying her eggs and immediately abandoning them by instinct and ignorance. For extinction, crashing comets and global dust clouds surely inspire more attention than gradually changing sea levels or solar outputs.

I wish that I could locate the current craze in these exciting intellectual developments. But a moment's thought must convince anyone that this good reason cannot provide the right answer. Dinosaurs might not have been quite so jazzy and sexy twenty years ago, but the brontosaurs weren't any smaller back then, the tyrannosaurs were just as fierce, and the whole clan was every bit as extinct (my camp friend's father notwithstanding). You may accept or reject Shep White's three categories, but choose any alternate criteria and dinosaurs surely had the capacity to inspire a craze at any time—twenty years ago as well as today. We must conclude, I think, that the potential has always been present in our century, that the missing ingredient was adequate publicity, and that the key to "why now?" resides in promotion, not new knowledge.

I must therefore assume that the solution lies in that great and dubious driving force of American society—marketing. At some definable point, some smart entrepreneur recognized an enormous and largely unexploited potential for profit. What craze is any different? Did goldfish reach an optimal size and tastiness for swallowing in the early 1940s? Did a breakthrough in yo-yo technology spawn the great passion that swept the streets of New York in my youth? Did hula hoops fit some particular social niche and need uniquely confined to a few months during the 1950s?

I don't doubt that a few more general factors may form part of the story. Perhaps the initial entrepreneurs developed their own interest and insight by reading about new discoveries. Perhaps the vast expansion of museum gift shops—a dubious trend (in my view), with more to lament in skewed priorities than to praise in heightened availability of worthy paraphernalia—gave an essential boost in providing an initial arena for sales. Still, most crazes get started for odd and unpredictable reasons and then propagate by a kind of mass intoxication and social conformity. If I am right in arguing that the current dinosaur craze could have occurred long before and owes both its origin and initial spread to a marketing opportunity seized by a few diligent entrepreneurs (with later diffusion due to odd mechanisms of crowd psychology that engender chain reactions beyond a critical mass), then the source of this phenomenon is not a social trend or a new discovery, but the cleverness of a person or persons unknown (with a product or products unrecognized). As this craze is no minor item in twentieth-century American cultural history, I would love to identify the instigators and the insights. If anyone knows, please tell me.

I do confess to some cynical dubiety about the inundation of kiddie culture with dinosaurs in every cute, furry, and profitable venue that any marketing agent can devise. I don't, of course, advocate a return to the ignorance and unavailability of information during my youth, but a dinosaur on every T-shirt and milk carton does foreclose any sense of mystery or joy of discovery—and certain forms of marketing do inexorably lead to trivialization. Interest in dinosaurs becomes one of those ephemeral episodes—somewhere between policeman and fireman—in the canonical sequence of childhood interests. Something to burn brightly in its appointed season and then, all too often, to die—utterly and without memory.

As intellectuals, we acknowledge and accept a minority status in our culture (since hope, virtue, and reality rarely coincide). We therefore know that we must seize our advantages by noting popular trends and trying to divert some of their energy into rivulets that might benefit learning and education. The dinosaur

craze should be a blessing for us, since the source material is a rip-off of our efforts—the labor of paleontologists, the great skeletons mounted in our museums. Indeed, we have done well—damned well, as things go. Lurking in and around the book covers and shopping bags are a pretty fair number of mighty good books, films, puzzles, games, and other items of—dare I say it—decent intellectual and educational content.

It is now time to segue, via a respectable transition, into the second part of this essay. (But before we do, and while I'm throwing out requests for enlightenment, can anyone tell me how this fairly obscure Italian term from my musical education managed its recent entree into trendy American speech?)

I need hardly say that primary and secondary education in America is in a sorry state, both by contrast with the successes of other nations and by any absolute standard of educational need in an increasingly complex world. I need also hardly say that the crisis is particularly acute for the teaching of science. Well, being of an optimistic nature, I survey the dinosaur craze and wonder why we are in such a bad way within our schools. The dinosaur craze has generated, amidst a supersaurus-sized pile of kitsch and crap, a remarkable range of worthy material that kids seem to like and use. Kids love science when it's presented well. If the dinosaur craze of pop culture has been adequately subverted for educational ends, why can't we capitalize on this? Why can't we sustain the interest, rather than letting it wither like the flower of grass, as soon as a child moves on to his next stage? Why can't we infuse some of this excitement into our schools and use it to boost and expand interest in all of science? Think of the aggregate mental power vested in ten million five-year-olds, each with an average of twenty monstrous Latin dinosaur names committed to memory with the effortless joy and awesome talent of human beings at the height of their powers for rote learning. Can't we transfer this skill to all the other domains—arithmetic, spelling, and foreign languages, in particular—that benefit so greatly from rote learning in primary school years? (Let no adult disparage the value of rote because we lose both the ability and the joy in later years.)

Why is the teaching of science in such trouble in our nation's public schools? Why is the shortage of science teachers so desperate that hundreds of high schools have dropped physics entirely, while about half of all science courses still on the books are now being taught by people without formal training in science? To understand this lamentable situation, we must first dispel the silly and hurtful myth that science is simply too hard for preadults. (Supporters of this excuse argue that we succeeded in the past only because science was much simpler before the great explosion of modern knowledge.)

This claim cannot be sustained for two basic reasons. First, science uses and requires no special mental equipment beyond the demands of the rest of the curriculum. The subject matter may be different but the cerebral tools are common to all learning. Science probes the factual state of the world; religion and ethics deal with moral reasoning; art and literature relate to aesthetic and social judgment.

Second, we may put aside all abstract arguments and rely on the empirical fact that other nations have had great success in science education. If their kids can handle the material, so can ours, with proper motivation and instruction. Korea has made great strides in education, particularly in mathematics and the physical sciences. And if you attempt to take refuge in the cruel and fallacious argument that Orientals are genetically built to excel in such subjects, I simply point out that European nations, filled with people more like most of us, have been just as successful. The sciences are well taught and appreciated in the Soviet Union, for exam-

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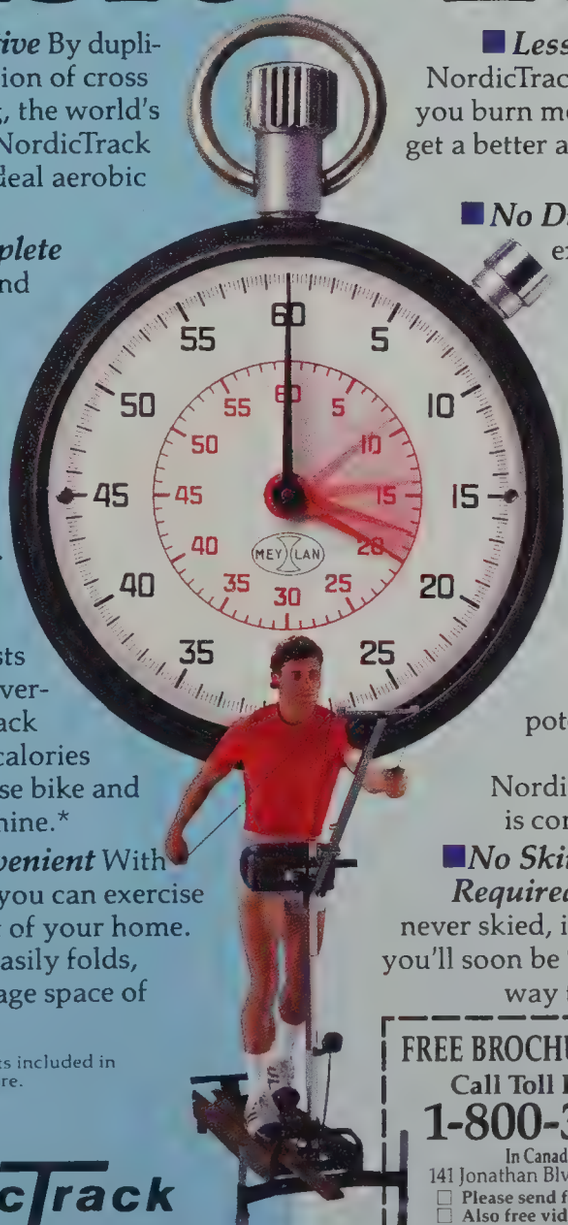

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ple, where the major popular bookstores on Leninsky Prospekt are stocked with technical books both browsed and purchased in large numbers. Moreover, we proved the point to ourselves in the late 1950s, when the Soviet Sputnik inspired cold war fears of Russian technological takeover, and we responded, for once, with adequate cash, expertise, and enthusiasm, by launching a major effort to improve secondary education in science. But that effort, begun for the wrong reasons, soon petered out into renewed mediocrity (graced, as always, with pinpoints of excellence here and there, whenever a great teacher and adequate resources coincide).

We live in a profoundly nonintellectual culture, made all the worse by a passive hedonism abetted by the spread of wealth and its dissipation into countless electronic devices that impart the latest in entertainment and supposed information—all in short (and loud) doses of "easy listening." The kiddie culture, or playground, version of this nonintellectualism can be even more strident and more one-dimensional, but the fault must lie entirely with adults—for our kids are only enhancing a role model read all too clearly.

I'm beginning to sound like an aging Miniver Cheevy, or like the chief reprobate on Ko-Ko's little list "of society offenders who might well be underground"—and he means dead and buried, not romantically in opposition: "the idiot who praises with enthusiastic tone, all centuries but this and every country but his own." I want to make an opposite and curiously optimistic point about our current mores: We are a profoundly nonintellectual culture, but we are not committed to this attitude; in fact, we are scarcely committed to anything. We may be the most labile culture in all history, capable of rapid and massive shifts of prevailing opinions, all imposed from above by concerted media effort. Passivity and nonintellectual judgment are the greatest spurs to such lability. Everything comes to us in fifteen-second sound bites and photo opportunities. All possibility for ambiguity—the most precious trait of any adequate analysis—is erased. He wins who looks best or shouts loudest. We are so fearful of making judgments ourselves that we must wait until the TV commentators have spoken before deciding whether Bush or Dukakis won the debate.

We are therefore maximally subject to imposition from above. This is a dangerous trait, but it can be subverted for good. A few years ago, in the wake of an unparalleled media blitz, drugs rose from insignificance to a strong number one on the list of serious American problems in that most mercurial court of public opinion as revealed by polling. Surely we can provoke the same immediate recognition for poor education. Talk about "wasted minds." Which cause would you pick as the greater enemy, quantitatively speaking, in America: crack or lousy education abetted by conformity and peer pressure in an anti-intellectual culture?

We live in a capitalist economy, and I have no particular objection to honorable self-interest. We cannot hope to make the needed, drastic improvement in primary and secondary education without a dramatic restructuring of salaries. In my opinion, you cannot pay a good teacher enough money to recompense the value of talent applied to the education of young children. I teach an hour or two a day to tolerably well-behaved near adults—and come home exhausted. By what possible argument are my services worth more in salary than those of a secondary-school teacher with six classes a day, little prestige, less support, massive problems of discipline, and a fundamental role in shaping minds. (In comparison, I only tinker with intellects already largely formed.) Why are salaries so low, and attendant prestige so limited, for the most important job in America? How can our priorities be so skewed that when we wish to raise the status of science teachers, we take the media route and try to place a member of the profession into orbit (with disastrous consequences, as it happened), rather than boosting salaries on earth? (The crisis in science teaching stems directly from this crucial issue. Science graduates can begin in a variety of industrial jobs at twice the salary of almost any teaching position; potential teachers in the arts and humanities often lack these well-paid alternatives and enter the public schools *faute de mieux*.)

We are now at a crux of opportunity, and the situation may not persist if we fail to exploit it. If I were king, I would believe Gorbachev, realize that the cold war is a happenstance of history—not a necessary and permanent state of world politics—make some agreements, slash the military budget, and use just a fraction of the savings to double the salary of every teacher in American public schools. I suspect that a shift in prestige, and the consequent attractiveness of teaching to those with excellence and talent, would follow.

I don't regard these suggestions as pipe dreams, but having been born before yesterday, I don't expect their immediate implementation either. I also acknowledge, of course, that reforms are not imposed from above without vast and coordinated efforts of lobbying and pressuring from below. Thus, as we work toward a larger and more coordinated solution, and as a small contribution to the people's lobby, could we not immediately subvert more of the dinosaur craze from crass commercialism to educational value?

Dinosaur names can become the model for rote learning. Dinosaur facts and figures can inspire visceral interest and lead to greater wonder about science. Dinosaur theories and reconstructions can illustrate the rudiments of scientific reasoning. But I'd like to end with a more modest suggestion. Nothing makes me sadder than the peer pressure that enforces conformity and erases wonder. Countless Americans have been permanently deprived of the joys of singing because a thoughtless teacher once told them not to sing, but only to mouth the words at the school assembly because they were "off-key." Once told, twice shy and perpetually fearful. Countless others had the light of intellectual wonder extinguished because a thoughtless and swaggering fellow student called them nerds on the playground. Don't point to the obsessives—I was one—who will persist and succeed despite these petty cruelties of youth. For each of us, a hundred are lost—more timid and fearful, but just as capable. We must rage against the dying of the light—and although Dylan Thomas spoke of bodily death in his famous line, we may also apply his words to the extinction of wonder in the mind, by pressures of conformity in an anti-intellectual culture.

The *New York Times,* in an article on science education in Korea, interviewed a nine-year-old girl and inquired after her personal hero. She replied: Stephen Hawking. Believe me, I have absolutely nothing against Larry Bird or Michael Jordan, but wouldn't it be lovely if even one American kid in ten thousand gave such an answer. The article went on to say that science whizzes are class heroes in Korean schools, not isolated and ostracized dweebs.

English wars may have been won on the playing fields of Eton, but American careers in science are destroyed on the playgrounds of Shady Oaks Elementary School. Can we not invoke dinosaur power to alleviate these unspoken tragedies? Can't dinosaurs be the great levelers and integrators—the joint passion of the class rowdy and the class intellectual? I will know that we are on our way when the kid who names *Chasmosaurus* as his personal hero also earns the epithet of Mr. Cool.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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How Cats Survive Falls from New York Skyscrapers

Science can progress even without controlled experiments

by Jared Diamond

I have never gone up the Empire State Building and never want to. I managed to get up the Eiffel Tower, barely, by closing my eyes in the elevator, holding my wife's hand tightly, and staying as far as possible from the edge when I reached the top. In Manhattan hotel rooms my legs lock when I look out the window to the street below.

All of you who share my fear of heights will understand these sensations. While my acrophobia is extreme, most people have some fear of falling, for good reason: falls are dangerous. With more than 13,000 fatalities each year, falls constitute one of the leading causes of traumatic death in the United States and are the most common such cause of death for children under fifteen. In New York City, falls account for one-fifth of all accidental deaths of children.

Even slips from a low stepladder often result in broken bones, but your chances of surviving a drop of fifty feet are only 50–50. Almost no one who falls off a six-story building onto a concrete sidewalk survives. Not surprisingly, jumping from buildings is a preferred means chosen by would-be suicides, and it's probably the most effective one. You might vomit the sleeping pills you swallowed, your hand may jerk as you pull the trigger, but nothing will save you once you've jumped off the ledge.

In all these respects, cats offer a startling contrast to humans. They are as nonchalant about heights as most of us are frightened, and they regularly survive falls that would kill any person. The explanation isn't that they rarely fall. Instead, in Manhattan, with its abundance of high rises, cats are more prone to fall than humans because they fearlessly play and chase each other along ledges. Even in my home town of Los Angeles, which has few skyscrapers, cats are still at risk of getting thrown off ledges of apartment buildings during earthquakes. Veterinarians see so many cats brought for treatment after a fall that there is now a technical term for the resultant pattern of injuries: "high-rise syndrome in cats."

Despite cats' propensity to fall, the outcome is far less often fatal to them than it is to us. It's not just that cats, unlike humans, commonly survive plunges from mere six-story apartment buildings. What's more impressive is that cats hurtling out of skyscrapers onto asphalt usually don't die as a result. Apparently the record (at least for New York City) is held by a kitty named Sabrina, who fell thirty-two stories onto a sidewalk and suffered nothing worse than a chipped tooth and mild chest injuries. Paradoxically, the *higher* the building beyond a certain height, the *less* risk a falling cat has of being killed! This ability to survive seemingly appalling drops is the main fact behind the adage that cats have nine lives.

Feline pesematology (from the Greek *pesema,* for "fall"), the science of falling cats, may not strike you initially as the stuff for which Nobel Prizes are won. But it is undoubtedly of emotional importance, as any concerned felophile (cat lover) knows. It might be of importance to human medicine as well, if understanding cats' survival secrets helps us to reduce our own fall-related injuries. What's more, feline pesematology illustrates the interplay between physiology and evolutionary biology, while also teaching us how to gain knowledge in fields where intentional experiments would be utterly reprehensible. Thus, falling cats yield poignant insights into the scientific method.

As in any science, let's start with the raw data. Feline high-rise syndrome was described in 1976 by Dr. Gordon Robinson, a veterinarian at the ASPCA's Henry Bergh Memorial Hospital in New York, to which owners were then bringing about 150 fallen cats each year. Eleven years later the next major advance was made by two other veterinarians, Drs. Wayne Whitney and Cheryl Mehlhaff, at the Animal Medical Center in Manhattan. Within one five-month period in the summer and autumn, the lure of open windows generated a data base of 132 cats admitted to the latter hospital after falls of at least 2 stories. Most falls were of 4 or more stories, with a mean value of 5.5 stories, standard error of plus or minus 0.3 stories, and maximum of 32 stories (the famous Sabrina). Most of the victims hit concrete pavement.

In their data analysis, Whitney and Mehlhaff had to discount 17 cats put to sleep at their owners' request—usually not because of a poor outlook, but rather because the owners said they couldn't afford medical treatment. Of the remaining 132 minus 17, or 115 cats, only 3 were dead on arrival. Eight more died within the next twenty-four hours, and all the 104 other cats that got through that first day

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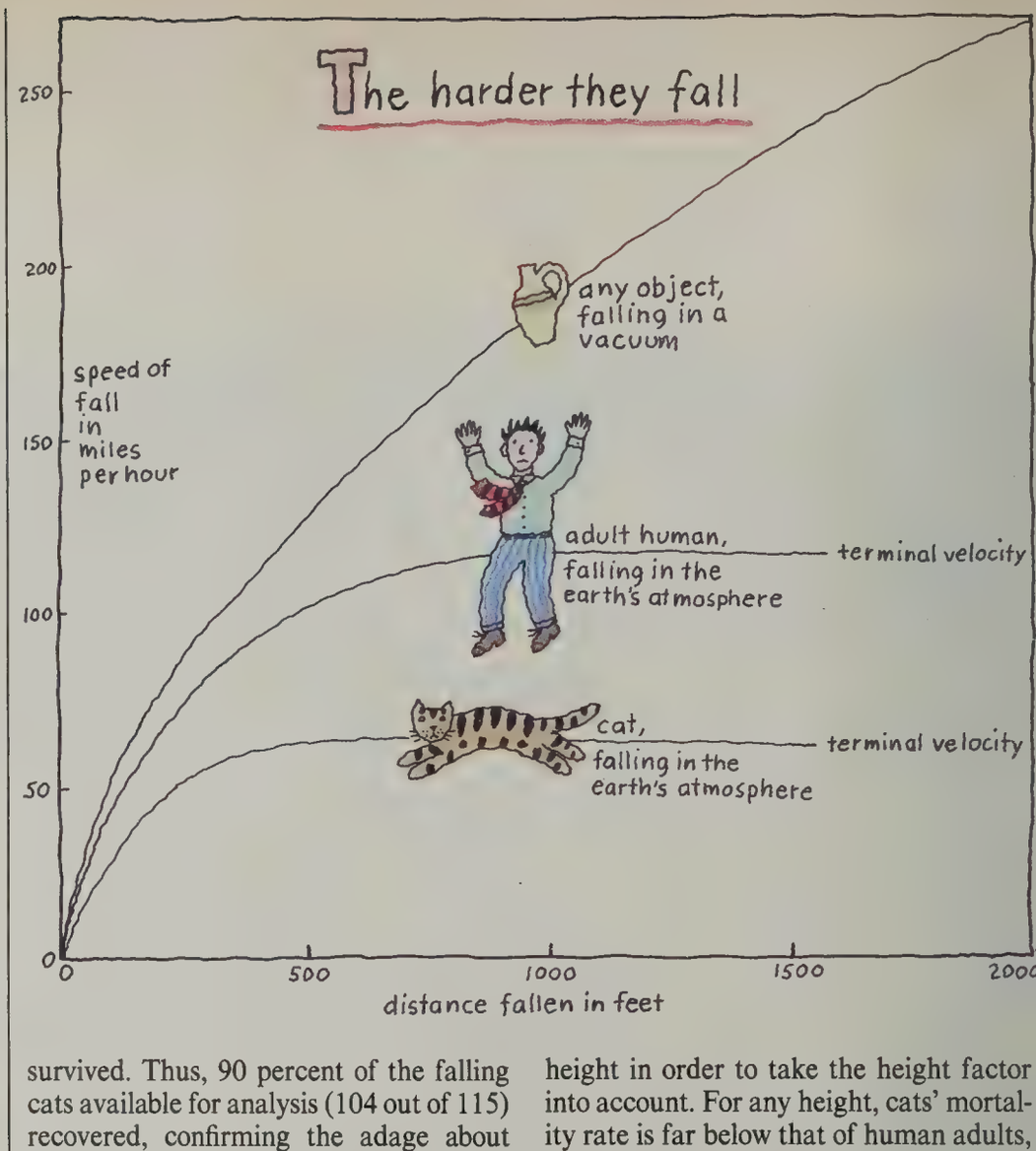

survived. Thus, 90 percent of the falling cats available for analysis (104 out of 115) recovered, confirming the adage about cats' nine lives.

The commonest injuries suffered by falling cats differ drastically from those of humans. Broken skulls and hemorrhage from internal injury are what kill falling people; broken backs and rib cages maim them. In contrast, one of the most frequent injuries to the cats was nosebleeds. That had not been among the risks on my mind as I stood with locked legs at the top of the Eiffel Tower, picturing myself splattered on the pavement far below. Falling felines also commonly suffered from facial lacerations, broken teeth, split palates or mandibles, and chest injuries.

Only three cats sustained the fractured vertebrae and four the broken ribs that are so common in humans. Like humans, cats often break limbs, but the pattern of limb breaks differs: adult humans most often break their legs, babies their arms, but cats break their forelimbs and hind limbs almost equally often. (Try to explain those differences now, without jumping to the end of this piece.)

Of course, falling cats differ most from falling people in their much lower death rate. Since fall injuries vary with the height of the fall, I've prepared a figure that plots mortality rate as a function of height in order to take the height factor into account. For any height, cats' mortality rate is far below that of human adults, while values for human babies are intermediate. Incredibly, cats' prospects for survival improve with height beyond seven stories: only 5 percent of cats that fell seven to thirty-two stories died, while relatively twice as many—10 percent—died from falls of only two to six stories. It's as if, confronted with someone threatening to throw you out a second-floor window, you could help yourself by begging him to throw you out a twenty-second-floor window instead.

So much for the raw data. To make sense of these puzzling results, let's turn to the deep theoretical insights that rigorous application of physical principles can offer us lowly biologists. Physics teaches that the outcome of a fall depends on impact velocity, compliance (softness) of the impacted surface, and five properties of the falling animal itself: its weight, surface area, surface compliance, bone parameters, and impact dissipation through joints and muscle.

As for impact velocity, your fall velocity accelerates by 22 mph with each second that you fall. For bodies falling in a vacuum, velocity increases as the square root of the distance fallen. By the time you've plunged thirty-two stories, you're

going at a bullet-train speed of 120 mph, but after two stories you've only gotten up to a sedate 30 mph. That explains my intuitive sense, while at the top of the Eiffel Tower, that I would make a bigger splatter on the pavement below from that height than from the top of a stepladder.

However, distance fallen isn't everything. The force on impact depends on the impacted surface's compliance, which determines its stopping distance (the distance you penetrate into the surface before you come to a full stop). The greater the stopping distance, the less the impact force. That's why pole-vaulters place a thick foam cushion rather than a concrete slab below the crossbar. For a modest sum (say, $10 million), even I would agree to jump once from an apartment roof onto a suitably thick and wide foam pad. That's also why the stories of pilots who survived falls from planes without parachutes refer to the lucky pilots who landed in mud (with a stopping distance of about eight inches), rather than to the unlucky pilots who landed on asphalt (stopping distance a fraction of an inch). As an alternative to landing on a compliant surface, you can also wrap yourself in your own compliant surface. Part of the reason that human babies survive falls better than adults is the cushioning effect of a baby's subcutaneous fat.

Theory also teaches us that a falling body's mass in relation to its area is important in two ways. First, impact force is proportional to mass. It's a delightful game when my 27-pound son Joshua jumps on my stomach, but it won't be so delightful if he wants to continue the game after he grows up to be a 270-pound NFL tackle. More specifically, what counts is the falling body's mass divided by the area over which the impact is distributed.

The other effect of mass and area involves air resistance as you fall. As we were all taught, Galileo supposedly proved that objects of different weights dropped from the Leaning Tower of Pisa strike the ground simultaneously. In fact, that result applies exactly only in a vacuum, where there is no air resistance to increase with velocity and to oppose the accelerating force of gravity. Eventually friction causes bodies falling in the earth's atmosphere to reach a certain terminal velocity, which they then maintain until they splatter on the ground below. The greater the body's area and the less its mass, the lower is that terminal velocity and the sooner it is reached. That's why paratroopers wear parachutes and why feathers hit the ground more gently than do cannonballs.

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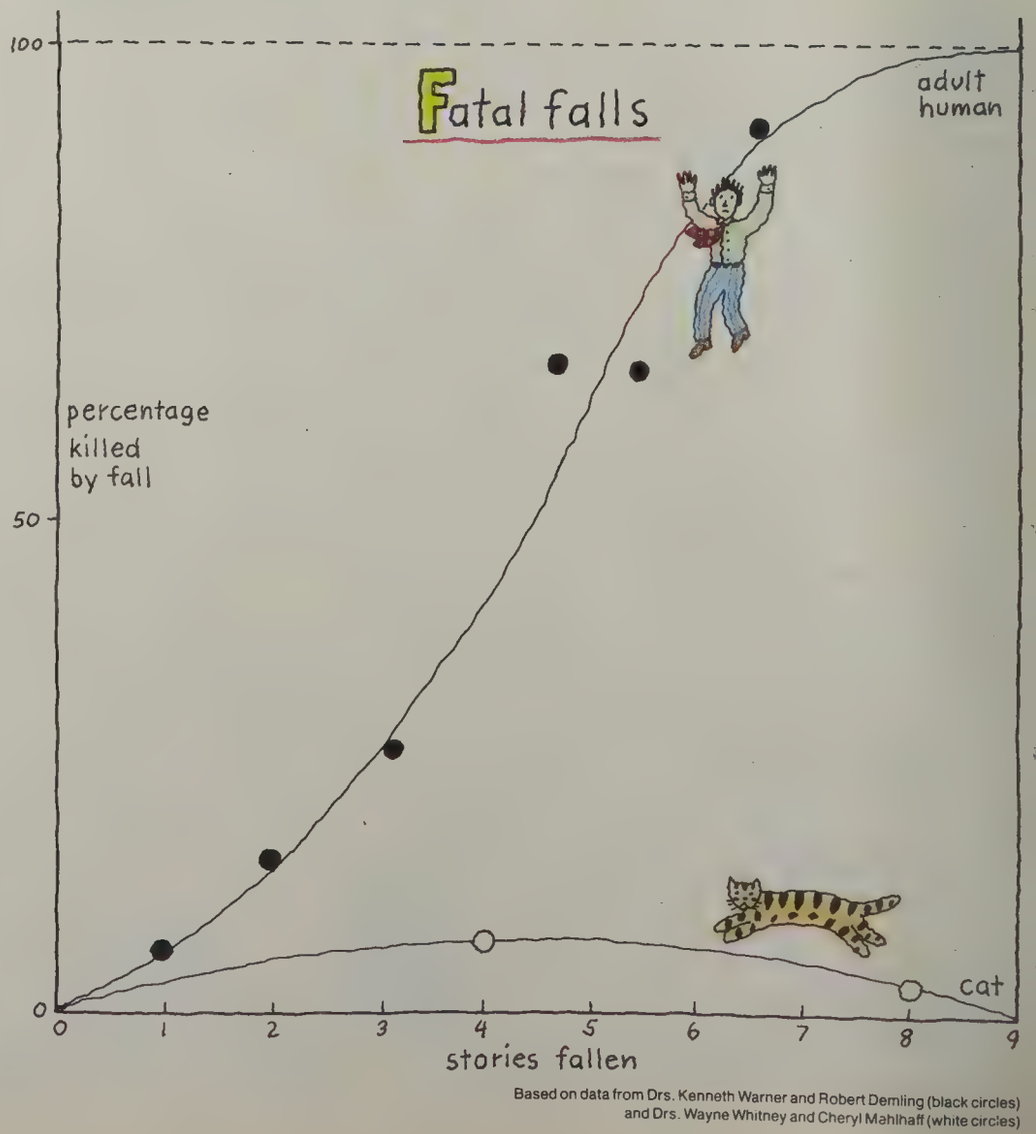
Now let's apply these physical principles to understanding the different injuries of falling human adults, babies, and cats. To begin with, humans are bigger than cats. Because mass increases with the cube power of linear dimensions, but area only as the square power, the mass-to-area ratio increases with body size. Hence we would hit the ground with more pounds per square inch than would a cat, even if our bodies were just a scaled-up cat's body and our landing positions were identical—which they are not.

You may object, correctly, that big animals have relatively stouter bones than do small animals, to absorb the greater impact. But the difference isn't enough to help. Elephants are much more at risk of a broken leg from a modest drop than are humans, just as adults are more at risk than babies, and babies more at risk than cats. Cats' lower ratio of mass to area also means that they reach a terminal velocity of a mere 60 mph within five stories of free fall, compared with our terminal velocity of 120 mph.

If cats were just scaled-down humans, that alone would make them less prone to injuries of falling than humans. But they have other unique advantages, beginning with a superb internal gyroscope located in the inner ear. If a cat starts to fall while upside down, it quickly detects its orientation, twists in midair, and has righted itself with all four legs pointing downward by the time it has fallen just two or three feet. The result is that it spreads the impact over all four limbs, not just two.

We adult humans, endowed with a much less efficient gyroscope, tend to tumble uncontrollably as we fall. We land most often on our (two) legs, next most often on our heads. Because babies have relatively large heads, they tend to fall head downward with their arms extended reflexly. These facts contribute not only to cats' better survival but also to their different injury pattern: equally frequent fractures of the forelimbs and hind limbs, as compared with the fractured skulls of humans of all ages, fractured arms of babies, and fractured legs of adults. (Did you guess that answer correctly?)

Another advantage of cats, apart from their small size, is that they land with their limbs flexed to distribute the impact force through their muscles and joints. While there's nothing we can do to acquire the feline gyroscope, their limb flexing on impact is something that we can indeed learn



Based on data from Drs. Kenneth Warner and Robert Demling (black circles) and Drs. Wayne Whitney and Cheryl Mahlhaff (white circles)

to imitate and thereby protect ourselves. Parachutists practice landing on their toes with their knees and hips flexed, then rolling successively onto their calves, thighs, buttocks, and back. In this way, they distribute the impact away from their rigid breakable bones, spread it over a large area of their body, and reduce the shock by thirty times or more.

None of these advantages of cats explains the most surprising result: their improved chances of survival if their fall exceeds seven stories. Recall that bodies falling in the earth's atmosphere accelerate up to a terminal velocity determined by their air friction (proportional to their area) and weight. Thereafter, their velocity remains constant—as long as their weight and area don't change. Weight of course can't change, but it's easy to change the area you present to the air rushing by. Free-falling parachutists decrease their area and increase their velocity by keeping a slim profile, and spread their arms and legs to increase area and brake their velocity.

Cats may be behaving like well-trained paratroopers. Until they reach terminal velocity, they reflexly extend their limbs, which are therefore prone to fracture on impact. After they reach terminal velocity and cease to feel gravity's acceleration forces, they may relax and spread their limbs horizontally, like a flying squirrel. This would increase their air resistance, decrease their velocity and impact force, and spread the impact over their whole body surface (not just over their four legs). Not only does this view of cats as skilled paratroopers account for their excellent survival of falls beyond seven stories but it also explains their greatly reduced risk of fractured limbs. Most cats that fell seven or eight stories suffered a fracture, but only one cat out of thirteen cats that fell nine or more stories did.

In short, falling cats are less at risk than falling humans for many reasons. Their small size means less impact force, less stress (force divided by area), and lower terminal velocity. All those features also favor other small animals besides cats, but falling cats are still less at risk than falling small dogs, because of further features unique to cats. These include their superb gyroscope, which lets them land legs first rather than headfirst; their flexed limbs, which spread the shock through their joints and muscles; and possibly their assumption of a flying squirrel configuration after they've reached terminal velocity.

Since we've now invoked physics, astronomy, and physiology to understand falling cats, it remains only to invoke evolutionary biology. I suggest that the

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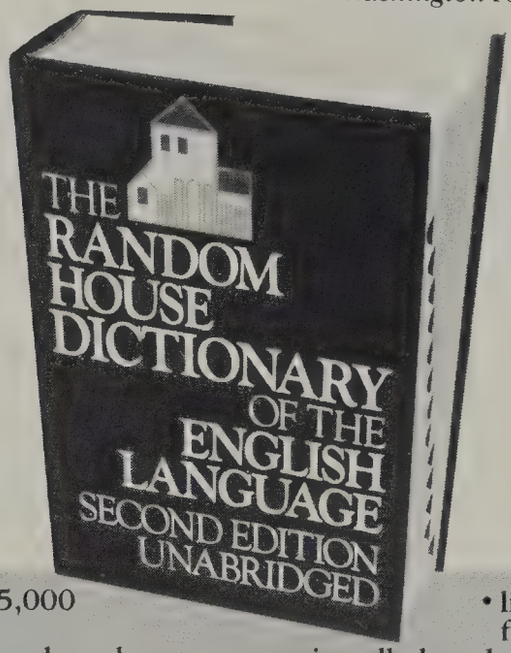

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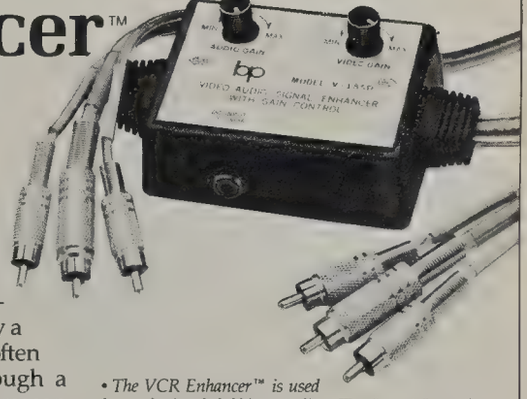

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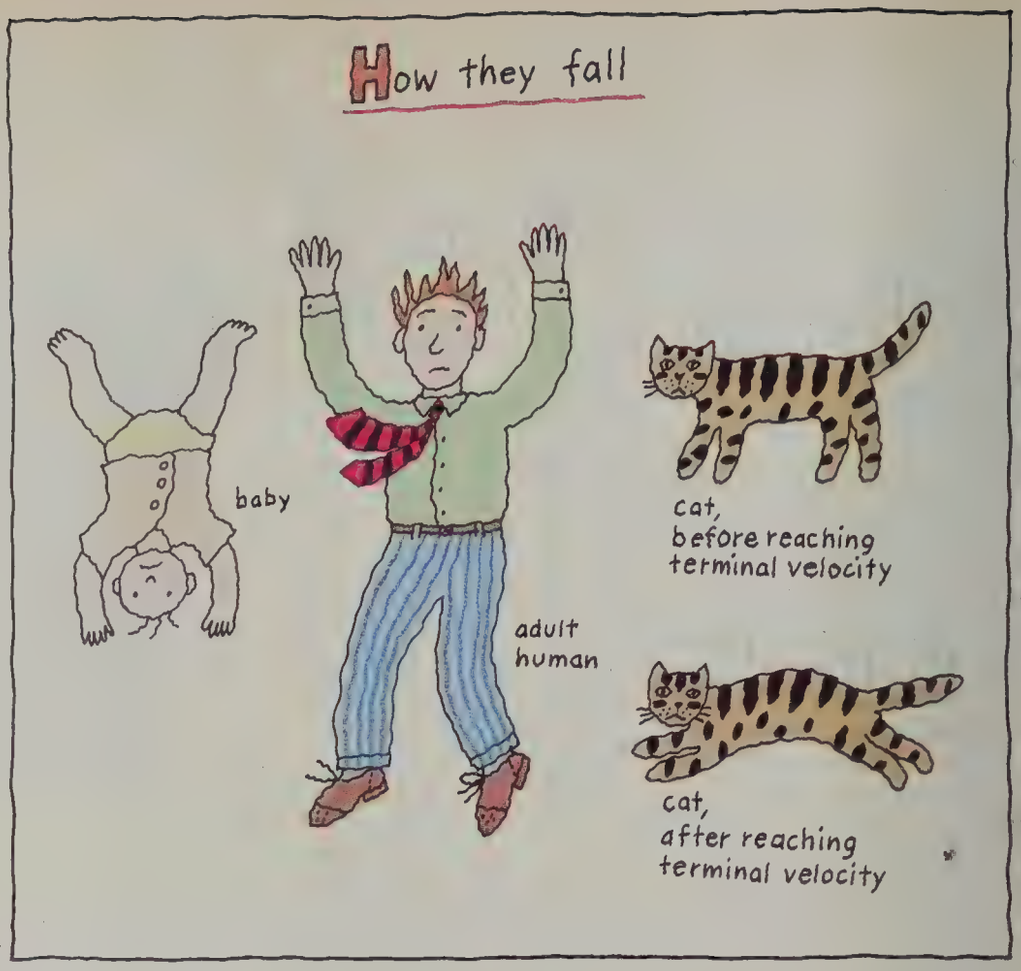

unique features of cats resulted from natural selection. Most wild species in the cat family, but few in the dog family, climb trees. For millions of years, cats have been intentionally springing from trees onto their prey, as well as falling out of trees accidentally. All those cats whose gyroscopes, limb flexing, and flying squirrel posture weren't up to snuff broke their legs and rolled into evolution's garbage can. Only the best feline paratroopers survived. Thus, cats ultimately have their evolutionary history to thank for their nine lives.

For those of you who aren't really into falling cats themselves, I'll close with a coda about their broader significance. Our first association to "scientific method" is likely to be "experiments." Supposedly, science tests conclusions by experimentally controlling the variables, preferably indoors in a lab. Some areas of science, like molecular biology, chemistry, and physics, really do fit that stereotype. But in other areas of science you can't possibly manipulate the variables. Perhaps the system is inaccessible or too big, as in astronomy or geology; perhaps it lies in the past, as in paleontology and archeology; or perhaps it would be unethical to manipulate variables, as in much of ecology and human research.

In these cases, scientists can still progress by searching for appropriate "natural experiments." That is, you don't manipulate the variables yourself; instead, you look for and compare existing situations where nature has already manipulated the variables for you. For instance, astronomers observe galaxies with different red shifts, epidemiologists compare human populations with different diets, and ecologists study islands with different sets of species. Scientists accustomed to manipulative experiments tend to be snooty about such research, but that attitude ignores the real difficulties of doing science on problems that don't fit in test tubes.

Injury patterns of falling animals provide a homely but clear example. We could gain insight rapidly by throwing various animals and people off buildings of various heights onto various surfaces. But laws and our consciences would block doing such experiments. Instead, we must rely on natural experiments and examine those unfortunate people and animals that fell naturally. The range of insights that Whitney and Mehlhaff were thereby able to extract illustrates how science progresses, even in those fields where controlled experiments would be immoral, illegal, or impossible.

Jared Diamond teaches physiology at the UCLA Medical School and studies New Guinea birds.

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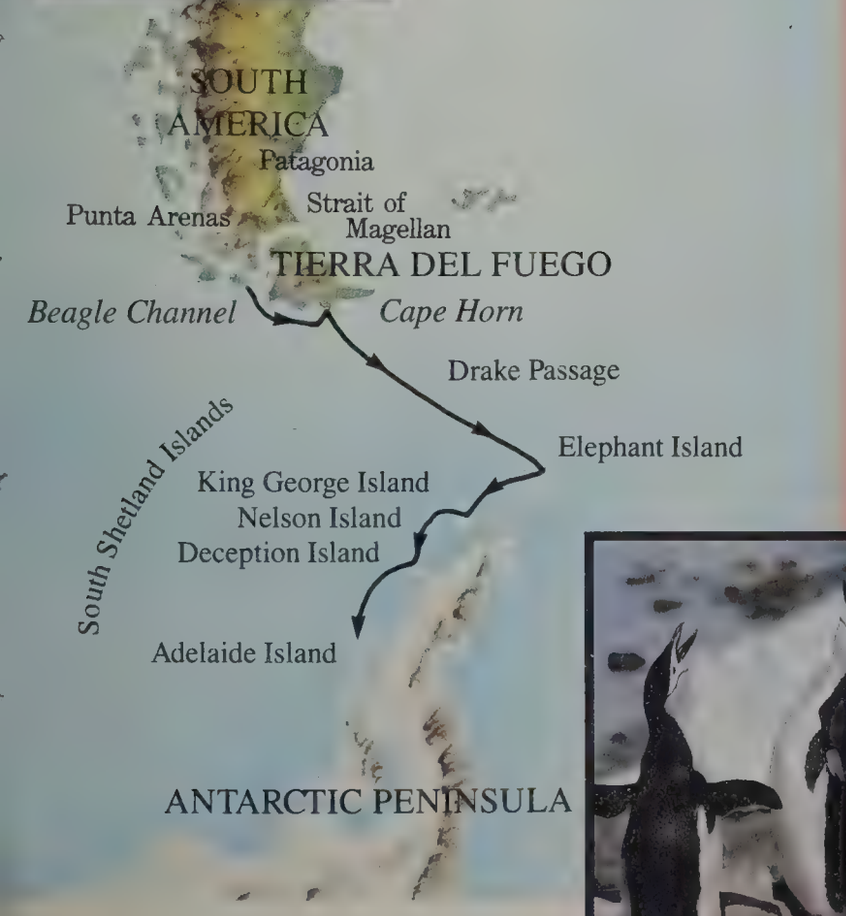

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On a rare clear day, Kraternaya Bay and the Pacific Ocean beyond shimmer in the sun.
Photographs by Michael V. Propp

Caldron in the Sea

Marine creatures find a volcanic oasis amid the chilly waters of the North Pacific

by Michael V. Propp and Vitaly G. Tarasov

The Ushishir Islands, Yankich and Reponkich, lie midway in the Kuril Island chain, which stretches from the tip of the Kamchatka Peninsula to northern Japan. Because they are surrounded by the Pacific Ocean on one side and the cold waters of the Sea of Okhotsk on the other, the two tiny islands are shrouded in dense fog during spring and summer. In the fall, typhoons batter them, and winter brings heavy snowfalls, making the islands among the most inhospitable and isolated places on earth.

In the center of Yankich Island, a spectacular bay lies hidden behind a high circular ridge. Linked to the sea by a narrow passage to the south, the bay is a submerged volcanic crater warmed by the earth's heat.

When a Russian named Ivan Cherny first visited Kraternaya Bay in 1769, he noted that on its southeastern shore sulfur colored the rocks with a yellow scum and two hot springs issued from the earth: "At night, young puffins flying toward the sea over these springs often fall in the water, overcome by the heat and sulfur fumes. The poor birds stew there, and soon only their feathers are seen in the water . . . the air is charged with sulfur, and fierce heat belches forth from the land in loud bursts." With volcanic steam rising from the springs and only seabirds nesting on the grassy slopes or an occasional arctic fox to be seen, the uninhabited island must have appeared as desolate to Cherny as it does today.

Cherny also wrote of the visits by the Ainu to the volcanic springs. The Ainu, who inhabited a few of the Kuril Islands, as well as Hokkaido, the northernmost island of Japan, came to the Ushishir Islands (an Ainu name meaning "good earth") to perform shaman initiation rites. Before becoming a priest charged with powers to control good and evil spirits, a young man would throw a piece of wood stamped with his personal brand into the boiling springs near the edge of the bay and make his wishes for the future. A platform was then built over the steaming waters with timber imported from other islands, and the shaman initiates, dressed in ceremonial furs, were bound to it. Intoxicated by the poisonous gases and heat and tortured by nightmares, they had to remain there for three days and nights. The Ainu believed that a man who endured the torture would be able to face any evil spirit and divert disaster from his tribe.

In 1985, we, too, were attracted to Yankich Island by the volcanic springs. As members of a scientific team from the Institute of Marine Biology in Vladivostok, we were the first to explore the waters of Kraternaya Bay and study the effects of volcanic activity on marine life.

Geologists have shown that the boiling springs that once served to initiate Ainu shamans have their origins in plate tectonics, the slow-paced movements of vast segments of the earth's thin skin. The Pacific plate moves northwest a few inches each year, and at the Kuril Trench its leading edge is subducted beneath the Eurasian plate. As it descends into the hot mantle, some of the Pacific plate melts and rises. Where the lava breaks through the crust, it erupts on the sea floor, gradually building the volcanic islands of the Kuril chain. Alaska's Aleutian Island chain, as well as

Joe LeMonnier

the island arcs stretching along the Pacific Ocean's western boundary down to New Zealand, was also formed in this way.

According to Georgii Gorshkov, a Soviet volcanologist, Yankich Island and its neighbor, Reponkich Island, are remnants of a single volcano, Ushishir, which once formed a much larger island with gentle slopes. Ocean waves, assaulting Ushishir from all sides, cut into the volcanic rock, leaving only the steep-sided central crater (Yankich Island) and an outlying portion of the volcano (Reponkich Island). The last major eruption, judging from radiocarbon dating of organic matter beneath a layer of pumice on the bottom of Kraternaya Bay, was about ten thousand years ago. Since then, extrusions of lava have raised four domes from the floor of the bay. (Two of the domes form small islands, and the fresh appearance of their rocks indicates that they were emplaced fairly recently, probably after 1769, since they are missing from Cherny's careful description of the bay.) For the most part, however, Ushishir has remained quiet. The thermal springs are the only reminders of the magma still present deep beneath the islands.

When volcanologists estimated that only 2 percent of the heat flowing from the volcano's deep interior was escaping as hot water from the vents along the bay's shore, they guessed that additional thermal springs might be found on the bottom of the bay. Using seismic waves to survey the island's subsurface, the scientists located a vertical fracture zone around the rim of the bay. Below the water and the thick marine sediments that fill the crater, the circular fault pattern outlined the core of the island that slid downward to form the crater.

After consulting with the volcanologists, we decided that the intertidal areas and deeper waters close to the crater rim were likely spots to find volcanic springs and study their associated sea life. The unusual marine ecosystems that thrive near hydrothermal vents have become a major area of research since 1977, when American oceanographers aboard the submarine *Alvin* descended to great depths on the Galápagos Rift in the eastern Pacific. Here they found tube worms, large clams, and other exotic creatures living around vents in the ocean floor where jets of water emerged, heated to several hundred degrees Fahrenheit by submarine volcanism. Unlike most life on earth, which depends on the sun's energy to power photosynthesis and produce food, vent organisms thrive in total darkness. The deep-sea organisms are supported solely by bacteria that use energy released from oxidizing hydrogen sulfide in the hot volcanic waters to build the organic molecules necessary for life. Following the discovery on the Galápagos Rift, scientists have located many similar deep-sea hydrothermal vent communities in ocean rift systems around the world.

Unlike the explorers of the deep-sea vents, who needed expensive submersibles to descend to the ocean ridges, we needed only scuba equipment to reach the bottom of the relatively shallow waters of Kraternaya Bay. On our first dives, we found hot water and gases issuing from numerous fissures on the bottom of the bay, as well as large areas where the bottom sediments were heated as the waters seeped upward through them; these two types of springs were in the waters near the crater's rim and corresponded to the fracture zones suggested by the seismic surveys. No vents were found near the middle of the bay where the water is al-

Steam and sulfur fumes rise from the field of boiling springs along the southeastern edge of Kraternaya Bay.

most two hundred feet deep, but several strong discharges were located along one crack at a depth of seventy feet. A profusion of colorful marine life was thriving on the bottom, particularly near the emerging volcanic water and gases. Although there were some similarities to the deep-sea vent communities, none of the strange tube worms or large vent clams of the deep-sea faunas were found in Kraternaya Bay. Instead we found a coastal marine ecosystem powered by a mix of typical photosynthesizing algae and plankton and by chemosynthesizing bacteria.

Many of the microorganisms that are the basis of Kraternaya Bay's food chain form mats on the crater floor as they do elsewhere in the ocean where light reaches the bottom. These mats contain a large variety of photosynthesizing algae and sulfur-oxidizing bacteria growing together in loose association. Their composition depends on how much sunlight they receive and on the temperature and chemistry of the water emerging from nearby springs, which may vary widely. The spring waters circulate deep within the island's porous rock after being drawn in from the cold seas. As they are heated and rise up through the fractures to the surface, they become charged with volcanic gases and enriched with sulfides, metals, and other elements dissolved from minerals in the rocks. Upon discharge into the bay, the volcanic waters cool as they mix with seawater, but near the vents the water may range from 50° to 100° F. These temperatures are quite warm compared with the 40° waters outside the bay.

In the intertidal areas and in the shallow waters near the shore of the bay, photosynthetic microorganisms, such as cyanobacteria (formerly called blue-green algae), purple bacteria, and algae, predominate in the mats. Also, an unusually large number of diatoms (photosynthetic protozoans with silica shells) contribute to the mats, which may be more than a foot thick. At deeper levels and under rocks where sunlight does not penetrate, chemosynthesizing bacteria become more important. These bacteria also dominate the cracks where the hot volcanic waters discharge and the concentrations of sulfides are the highest. Sulfides are toxic to most organisms. In higher animals the effect of sulfides is comparable with that of cyanide. In the blood, sulfides bind to the hemoglobin molecules, displacing the oxygen that they normally carry; because the blood is no longer able to transport oxygen throughout the body, respiration is prevented. Most of the poisonous sulfides are removed from the water almost immediately after emerging from the vents; oxidized by the bacteria and by contact with the seawater, the sulfides are converted to nontoxic elemental sulfur, which settles onto the mats, coating them with a white film. In this state the sulfur is used again by other bacteria that convert it to sulfate, the end product.

Two species of archaebacteria recently discovered at the deep-sea vents were also present here. (Studies of their genetic material, conducted by other researchers, suggest that archaebacteria are fundamentally different from other bacteria; and because they are found living in extreme conditions similar to those of primitive earth, they may represent a more ancient form of life.) Unlike the other chemosynthesizing bacteria, archaebacteria do not need oxygen to burn sulfur; all they require is elemental sulfur and hydrogen. Living in the bottom sediments and in crevices rich with sulfur, they can survive at temperatures as high as 160° F.

Plankton, consisting of photosynthetic algae, bacteria, and protozoans, also contribute heavily to the bay's primary food production. They, too, benefit from the volcanic waters, which contain important inorganic nutrients, such as phosphorus and nitrogen in the form of ammonia. At the surface of the open ocean, these essential nutrients are limited, restricting the growth of plankton; only near shore and in areas of upwelling, where nutrients are brought to the surface from the bottom, are high concentrations of plankton found. Because Kraternaya Bay is a relatively closed system, with only a narrow, knee-deep channel connecting it to the sea at low tide, both inorganic and organic nutrients are continuously recycled in the bay,

A garden of tube anemones, right, thrives on a bacterial mat at the bottom of the bay, more than sixty feet down. The animals disappear down their tubes at the slightest disturbance. A white, cobweblike film of sulfur from nearby hydrothermal vents coats the mat. Below: Delicate sulfur crystals grow around the mouth of a fumarole on the bay's shore.

providing ideal conditions for the reproduction of microorganisms.

Each year since 1985, expeditions from the Institute of Marine Biology have returned to study the ecosystem in Kraternaya Bay, where the energy available for life is used in interwoven and constantly changing pathways. Because of the movement of tides and rising volcanic water, the bay lacks well-defined water layers, making accurate estimations of production and destruction of organic matter in this complex environment extremely difficult. Although we are unable to measure precisely the relative roles of chemosynthesis and photosynthesis in the bay, the dense population of organisms covering the bottom is evidence of its high production of organic matter.

The food produced in this rich environment is transferred up the food chain by a variety of single-celled animals that live in the mats and waters and consume the bacteria and algae. Those protozoans that are known as flagellates feed on the mat products by night and propel themselves with tiny, whiplike appendages to the surface, where they use self-contained chlorophyll to photosynthesize additional food during the day. Many invertebrate larvae and tiny crustaceans also dwell in the bay, feeding on the smaller planktonic organisms, and nematode and polychaete worms graze in the mats.

The large invertebrates that cover the bottom of the bay often exceed in density the animals found in tidal areas along the coasts, but they are not as diverse. Only 150 species are found in the bay, about half the number found in the surrounding seas. Most are previously known species, such as sea urchins, barnacles, and sponges, that have the ability to adapt well to constantly changing conditions.

A few new species were found in the bay, however. Among them are conspicuous bright-red sea cucumbers (*Psolus*), which form a dense cover on the bottom rocks, and a white species (*Eupentacta*) previously known only from the Aleutian Islands. At deeper levels, large anemones of the genus *Cerianthus* live on the muddy bottom, each in its own long, curved tube, to which it retreats at the slightest movement in the water. The tube anemones are particularly numerous near the vents, along with a new species of clam of the genus *Macoma*.

One species found in the bay, a clam in the genus *Axinopsida*, has been shown to have a symbiotic relationship with chemosynthetic bacteria living in its gills; the clam filters hydrogen sulfide from the water for the bacteria, which, in turn, contribute organic nutrients to their host. Like the large clams found around the deep-sea hydrothermal vents, *Axinopsida* may have evolved a special molecule that transports sulfides to the bacteria without poisoning itself. As work continues on the bay's biology, we hope to confirm other such symbiotic relationships and perhaps determine the mechanism the clams have evolved to avoid the toxic effects of hydrogen sulfide.

In contrast to the animals surrounding the deep-sea hydrothermal vents, where almost all the organisms were previously unknown, those in the bay do not differ significantly from their relatives in other coastal areas. But the few new species are of great interest to specialists in invertebrate zoology and evolution. As the bay is young in geologic terms, these new species may have evolved rapidly from coastal relatives in order to cope with this unusual environment.

Given the relatively brief time allowed for the evolution of new species specifically adapted to conditions in the crater, however, the possibility exists that some of the animals may have evolved in the vicinity of distant volcanic vents and been transported by currents to the bay. At deep-sea vents, the organisms have evolved to fill these isolated volcanic niches and cannot survive elsewhere. New vents are populated by recruits in the form of larvae or spores that drift on bottom currents from well-established communities. The same species are often found at hydrothermal vent sites located hundreds of miles apart along the ocean ridges.

We are planning another expedition to the Kurils next year. And since the island chain has at least a hundred volcanoes

(about a third are listed as active) and more than a hundred known submarine volcanoes, we hope to find additional coastal, and perhaps deep-water, volcanic-vent communities. One was, in fact, already found two years ago off Kunashir Island in the southern Kurils, where bacterial mats and dense populations of anemones were discovered offshore at the foot of the Mendeleev Volcano. And last year, mats were found in several more localities around Kunashir Island at depths of less than forty feet.

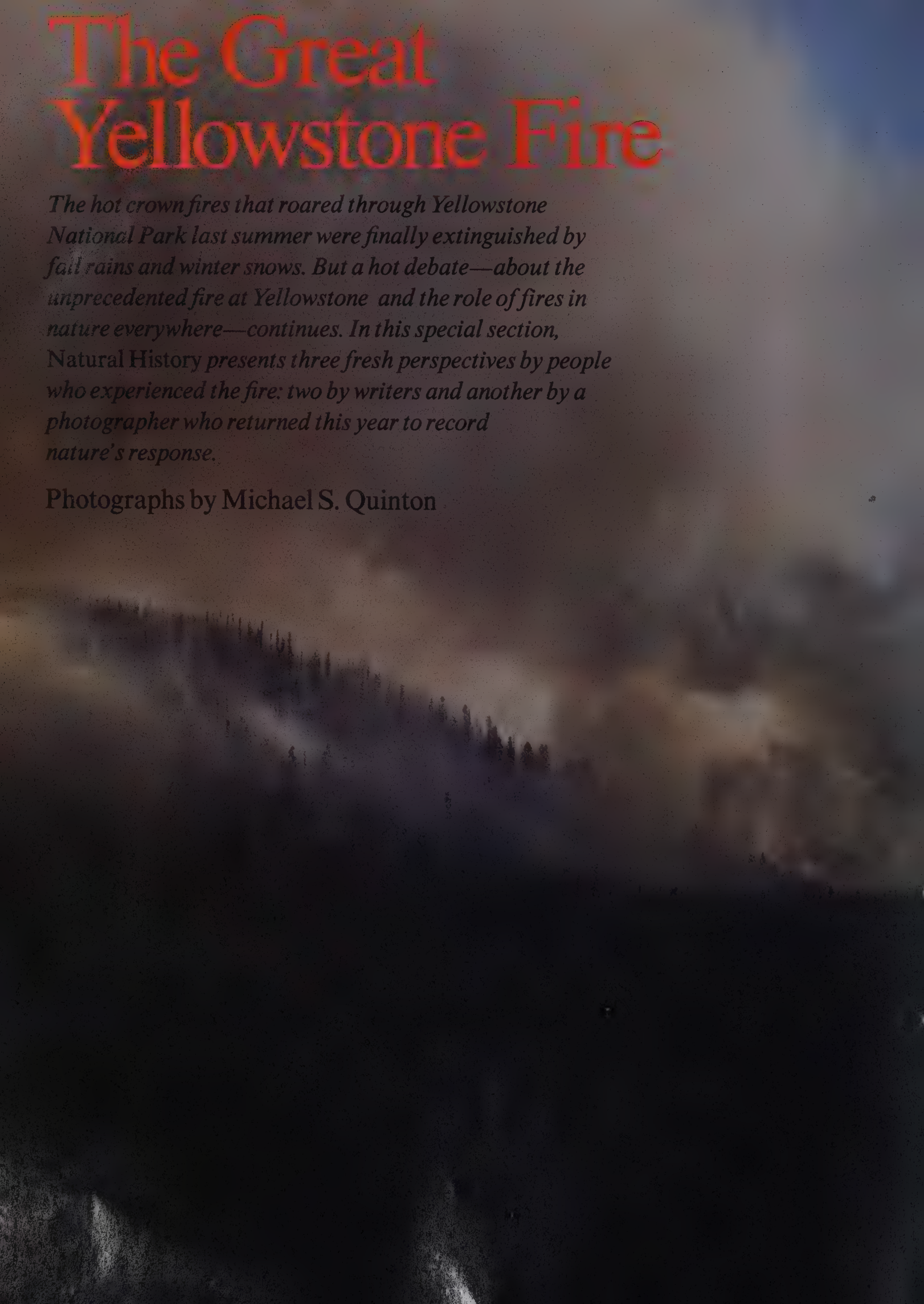
Although other places may increase our scientific understanding of these ecosystems, none are likely to match the beauty and solitude we found at Kraternaya Bay. The calm and peace that reign here during our short summer visits remind us of high mountain lakes in tranquil weather. The steep cliffs, overgrown with grasses of various colors and towering more than a thousand feet above the water, protect the bay from strong ocean winds. Seals and sea otters, which thrive among the thick kelp beds of the Kuril Islands, find shelter in the bay when storms rage along the open coasts. The rocks that stand as sentinels at the entrance of the bay are animated with stormy petrels, guillemots, puffins, and others seabirds, numbering in the hundreds of thousands. Arctic foxes run among the boulders that lie scattered about the islands, searching for prey. Without fear of man, these animals approached us closely, often nibbling at our rubber diving suits, which seemed to attract them.

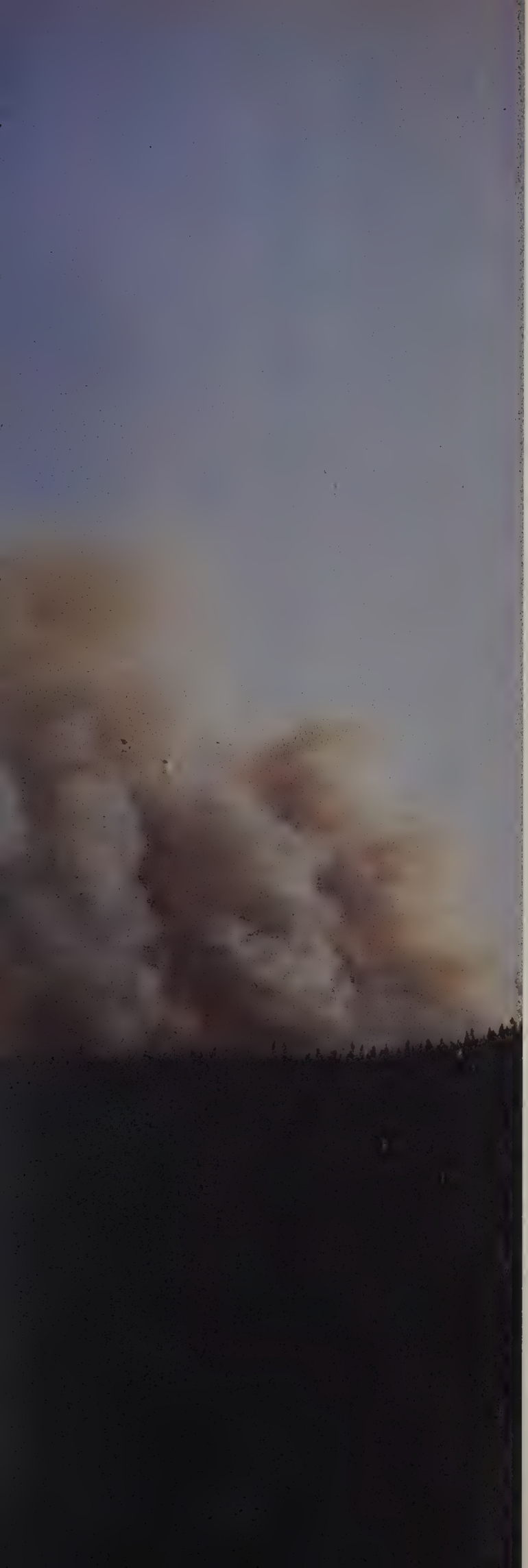
The islands are a rare memorial to undisturbed nature. Except for a few scientific expeditions, the Ushishir Islands are rarely visited by humans. In 1987, Yankich Island was designated a protected nature preserve; along with animals and plants, microorganisms and protozoans are also protected here, a rare practice in natural preservation. A sacred place for the Ainu, where the shaman initiates faced the most evil spirits nature could provide, Yankich has become a permanent memorial to the wild. □

The Great Yellowstone Fire

The hot crown fires that roared through Yellowstone National Park last summer were finally extinguished by fall rains and winter snows. But a hot debate—about the unprecedented fire at Yellowstone and the role of fires in nature everywhere—continues. In this special section, Natural History *presents three fresh perspectives by people who experienced the fire: two by writers and another by a photographer who returned this year to record nature's response.*

Photographs by Michael S. Quinton





A Smoke-scented Diary

On June 23, 1988, lightning struck, sparking a small fire near Shoshone Lake

by Carol A. Shively

For nearly a month, the Shoshone Fire, as it came to be called, behaved as fires normally do in Yellowstone, which is to say it did practically nothing. Then, in a matter of days, high winds whipped it to several times its original size and drove it to within a mile of the lodgings and campgrounds of Grant Village.

On the night of July 22, the decision was made to evacuate the village. I expected chaos at the campfire program that evening. Announcing to more than 500 people assembled in an amphitheater that they would need to evacuate the area by nine the next morning is rather like shouting "Fire!" in a crowded theater. But chaos didn't happen. At seven the next morning, the rangers took their places in assigned loops of the campground, systematically noting when each campsite was vacated to make certain that the entire area was cleared of visitors. At 8:45, some campers were still flipping pancakes and offering us coffee. A few friendly reminders and suggestions about where to camp, and they were on their way. I heard over the park radio that the concession managers had completed the evacuation of all their employees, as well as guests. In all, three thousand people had been evacuated with orderly precision.

Back in the employee housing area, I heard someone say, "We have to be out by ten o'clock." If you've ever gone through the mental exercise of wondering what you would take with you if you had only a short time to pack because of a fire, you have a hint of what, for us, became sudden reality. While we were lost in thought, all around us the defense of Grant Village had begun. The sound of chain saws ripped through the air as fire crews started cutting down any trees that might fall and set a building on fire. All dead and fallen wood was hauled away, including cords of firewood that had been carefully stacked months earlier. In our haste to leave, important papers and precious possessions, such as homemade quilts, were left behind. As we drove away, I took a long look back at my home and half wondered if it would still be there when I returned.

Already, accusing headlines spoke of a failed fire policy. The park's fire management plan calls for suppressing all fires caused by humans, while allowing naturally caused fires to burn unless they threaten human life and property. At the time, however, the decision of whether or not to suppress the Shoshone Fire was not as obvious as some might think. Eleven of twenty other lightning fires that year had already burned themselves out. Since history has been recorded in Yellowstone, rain has extinguished the average fire after one acre has burned. And rainfall for April and May had averaged 186 percent of normal.

One has to wonder if anyone could have envisioned or foreseen the magnitude of an event that no one living in this part of the country had ever seen.

By this time, lightning had ignited other blazes in and around the park: the Fan, Falls, Red, Lava, Clover-Mist, and Mink fires. But after the high winds of mid-July and the absence of rain, it was clear that fire was not going to behave as it had for the last hundred years. Full suppression was ordered on all fires.

By late in the afternoon of the evacuation, a Type 1 Incident Command Post was established in the Grant Village campground. Whenever a major incident occurs, whether it requires firefighters or a search or rescue party, an incident command team—a group of highly trained people from land managing agencies across the nation—is summoned. These are the experts. Gone were the campers with colorful tents and laughing children with fishing poles in hand. A guard was posted at the fire camp entrance. Hundreds of firefighters dressed in green-and-yellow fire-resistant Nomex uniforms walked in disciplined ranks with fire tools in hand. Helicopters flew overhead.

The incident command team formulated its plan. The idea was to fight fire with fire. The surface of a large swath of land would be burned around the Grant Village structures, so that when the fire approached, there would be few ground fuels left to catapult the fire up into the trees. With fewer fuels, the fire would burn less intensely and could be directed around the village. I found it hard to believe that anyone could tell this fire what to do, but I fervently hoped it was possible.

Tactical fires, such as this "burn-out" procedure, are only started when they are "within prescription," that is, within certain climatic parameters such as temperature, humidity, wind speed and direction, and fuel moisture. These guidelines are meant to insure that the fire is part of the solution, rather than part of the problem. A set of weather readings was taken. The prescription had been met. It was time to move.

Hand crews with drip torches walked through the forest, leaving a wake of flame. A terratorch shot an arc of flame deep into the trees, and a helitorch dropped time-released firebombs from above. Within minutes, the area was engulfed in flames. Fire engine crews stood poised and ready to protect the buildings as the fire came near. By the end of the day, the battle line had been drawn. Over the next several days, when tested by the full force of the fire, we would know if it would hold.

As the week progressed, the Shoshone Fire approached, burning to the north and to the east but leaving Grant Village intact. The battle to protect the structures had been won.

For everyone involved in the Yellowstone fires, one day probably stands out from all the rest. For me, it was July 31, the day the fire reached West Thumb. The area ranger, Doug Ridley, ordered the area closed to the public.

The operations chief of the incident command team closed the door of his truck and strode toward me, saying, "You'd better get these people out of here, the fire's getting ready to come over the hill." Immediately another ranger, Roger Anderson, and I cleared visitors out of the West Thumb store and then headed down to evacuate the geyser basin—a more challenging task. Most of the visitors perceived that danger was relatively near and quickly obliged us. Others, however, were reluctant to leave. I couldn't entirely blame them. They were captivated by the billowing cloud of smoke rising to the north, the helicopters dipping low to fill their water buckets in the lake, and a moose and her calf wading just off the lakeshore. With some effort, we were able to convince them that it was wise to move on, and the area was secured. Then the wait began.

I'm not a stranger to fire. Although it's not a primary duty of my position, I carry a "red card" in my wallet that qualifies me as a firefighter. My park service career began in the chaparral-covered Santa Monica Mountains, where fires jump eight lanes of freeway. No firebreak seems sufficient to stop them save the

Madison plateau, near West Yellowstone, Montana

Pacific Ocean. Still, I was not prepared for what I would see this day. Some of the incident commanders have since said that this was a once-in-a-lifetime experience. Even they had never seen fire burn as it did in Yellowstone in 1988.

Engine crews were in place to protect the buildings at West Thumb. As the smoke became thicker and thicker, it obscured the sun and gave this once-bright afternoon the appearance of evening. The winds that had challenged us earlier never seemed more menacing than now, blowing thirty to forty miles per hour and gusting up to sixty.

You hear a fire before you see it. Suddenly, a tremendous wind swept through the area. I never knew wind could be so loud. The engine crews continued to foam down the few structures at West Thumb. I looked back at them. One was the ranger station. Built in 1925, it was one of the first in the national park system. In winter, it serves as a warming hut. I'd started many fires in its wood stove and learned the magic of winter there. I found myself feeling strangely sentimental about it.

And then it came. Tongues of flame whipped through the air, and the fire seemed to roll over the horizon toward us. It would have to cross the road before reaching us in the parking lot. Usually, a road is a sufficient firebreak to slow a fire in a lodgepole pine forest, but not this one. With terrific force, the wall of flames approached the road just south of West Thumb, hesitated slightly, and then rushed up on the other side. Under normal circumstances, a large parking lot, with a dozen fire engines and surrounded by a meadow, would be a safe place. But weather conditions were extreme, and nothing was "normal" this year. While the veteran firefighters were calm, I found myself keeping one hand on the emergency fire shelter I wore on my belt. These are fire-retardant tents that every firefighter carries, to be used as a last-ditch attempt to survive if overcome by fire.

By now the fire was crowning in the trees around the meadow. It was, in a word, awesome. I experienced a full range of emotions this summer, including some I'd never known before. At this moment, a strange, yet peaceful fascination overcame my fear as I stood mesmerized by the sheer power before me. There are a few times in our lives when we witness something so extraordinary that our minds must stretch to include it. For me, this was one of those times.

In a blaze of glory, the east flank of the fire ended its dramatic run at the lakeshore. When it was over, the ranger station was still standing, and the meadow, as well as many of the trees, had hardly been touched. It was a lesson to me in fire behavior: the wind can drive a fire so fast and so hard that it jumps huge areas. Few fires, even one as wild as this, consume everything in their path.

"Of course they don't." She didn't say it, but it was implicit in the look in her eyes. It was that moose again. I recognized her. She and her calf lived behind the residential area, and after a while one gets somewhat acquainted. After having spent the afternoon wading in the lake, she was taking her calf back toward Thumb Creek where there would still be plenty of grass on which to graze. I watched that moose until she and her calf disappeared completely into the forest. It was a far cry from the fire chase scene in the movie *Bambi*, on which my generation was raised. It occurred to me that humans are the only animals that perceive fire as a crisis.

Reports show that of the more than 25,000 large mammals in Yellowstone, between 300 and 400, less than 2 percent, were lost to the fires. Later, I had the chance to fly over the park. I was amazed at what I saw: acres of land, which according to the fire maps had burned, were untouched; hundreds of elk grazed quietly as if wholly unconcerned about the fire. I was reminded that Yellowstone is such a vast and wild place that even this event, which was making and breaking records and which dominated our lives for a time, seemed relatively small in the grand scale of Yellowstone time.

I'm a believer in fire. I can't help but be. I spent two years in California's Sequoia and Kings Canyon national parks where, because fires were suppressed for a hundred years, new generations of the majestic old trees were nearly aborted. The existing trees had been protected, to be sure, but there were very few young sequoias to speak of. When superheated by fire, sequoia cones open and release their seeds. We learned a valuable lesson there. In the national parks, we're not protecting things, we're protecting processes.

Similarly, lodgepole pine cones need fire. After several

Elk female and two young, Madison River

centuries, many of the trees have died and fallen, leaving a dense mat of dead trees awaiting a major fire to open their cones and release the seeds of the new forest.

Just the same, while walking through the back basin at West Thumb soon after the fire, I had mixed emotions. This area had burned intensely. All that appeared to remain were ghostly black snags reaching up through a smoky gray haze. The back basin had been a special place for me. Lush and green, it was a quiet retreat from the frenzied pace of summer. I would miss it. I felt the sorrow of a friend lost. And yet, looking closer, I saw that within a month, vibrant, green grasses had begun sprouting up everywhere. Many of the serotinous cones had already opened in a celebration of new life. There, lying on the ground, were the seeds of the next generation. Insects had enthusiastically taken up their new homes, and they, in turn, attracted a host of animals and birds. The senescent and dying lodgepole forest was springing to life again.

History tells us that a fire of this magnitude occurs once every 200 to 400 years, and this was the year. As one visitor expressed it, "When Nature decides to clean house, nothing's going to stop her." For those who say that "the park will never be the same in my lifetime," I can share their grief over the loss of what was. But I encourage them to think of what will be. Telling a fire not to burn in a forest is like telling a child not to grow up or the tide not to come in. What was it that created the green carpet of forest that we recall with such fondness? A cataclysmic fire, much like this one, some 300 years ago. We are standing at a turning point in history, the birth of the new Yellowstone. Although the fire has created an artistic array of visual contrasts, beauty is in the eye of the beholder. Some will say, "It's not pretty," and I wouldn't try to convince them otherwise. Birth never is. But from what I understand, the rewards are well worth the cost.

At 2.2 million acres, Yellowstone is a relatively vast area, dedicated to letting nature do generally as she pleases. But that summer, political boundaries could not hold her. Within the park, fire is seen as an essential force of nature, like the sun, the wind, and the rain. When it leaves the park, however, it is viewed quite differently. Our concern soon shifted to protecting the small communities outside Yellowstone.

As the threat of fire moved beyond Grant Village/West Thumb, we were able to reopen the area to visitors. Day after day, I posted the weather forecast: high temperatures, high winds, no precipitation. Looking up at the sky, I wondered where the rains were that had managed these fires for decades. This year, they just didn't come. I saw only the red sun peering through the smoke.

The skies were orange over Yellowstone in August. Nighttime usually provided a respite from the flames, but not this year. The fires burned through midnight. The North Fork Fire, purportedly started by a woodcutter outside the park, had made several dramatic runs, jumping two roads and a river. It now threatened Norris. Driven by high winds, all the fires were throwing embers as far as a mile ahead, starting yet new spot fires.

I remember driving in the west entrance through Madison Junction one evening with a friend who had just arrived in the area. The fire illuminated the sky and burning trees fell across the road, creating a sense of the surreal. Here and there in the darkness, a tree would ignite and flash like a torch in the night. For my friend, it was probably a harrowing and unforgettable experience. For me, it was just another day. After a while, the mind becomes numb to even the most spectacular event. One

day simply blended into the next like a dream that wasn't going to end. At times, it seemed as though the gentle snows of winter would never fall.

August 20 became known as Black Saturday. Grant Village was evacuated for a second time, and this evacuation was not as leisurely as the first. Although fire behavior depends on factors such as vegetation type and climate, for some people there was the strange perception that the fire had a mind of its own and was storming across the map and across the land like a mythical monster intent on devouring the entire Greater Yellowstone area. Now it was coming perilously close to several communities outside the park.

Labor Day weekend has always been a time of rest in Yellowstone. The rush subsides, and the sound of bugling elk signals that fall has come. This year, the elk continued their age-old tradition, but for the thousands of firefighters, it was far from a time of rest. The summer had been long, but the full fury of the fire was yet to come. Each morning in the fire camp, the computer printed out the status of each of the nine fires in the park and surrounding area. Most reported, "No estimated date of containment."

The nine incident command posts, now joined under the Greater Yellowstone Area Unified Command, were throwing everything they had at the fires, including more than 9,600

firefighters, 105 fire engines, 40 helicopters, 21 bulldozers, and several planes. Some progress was being made. The Fan Fire, in the northwest corner of the park, had been contained. The fire lines around our own Shoshone Fire (now combined with other fires into the Snake River Complex) were holding well. Firefighters were aggressively attacking the Clover-Mist Fire, which, although burning out of the park into the national forest, had taken a turn away from the communities of Silver Gate and Cooke City. The change in wind direction was a stroke of luck for these towns, but the south flank of the fire now moved toward Fishing Bridge.

People will probably always remember all of the fires of 1988 as Yellowstone Park fires. In reality, only some of them started in the park. Of equal concern were those we had inherited from outside.

The North Fork Fire had made a thirteen-mile run in one day, causing the evacuation of Island Park, Idaho. At the same time, erratic wind changes drove the other flanks of the fire at West Yellowstone, Montana, and Mammoth Hot Springs, Wyoming. The North Fork Fire had become so large that it was split administratively to be fought as two fires. A new incident command team fought its eastern flank, now called the Wolf

Left: Aspens, stripped of bark, and shed elk antlers, Elk Creek, spring 1989. Overleaf: Elk, Gibbon Meadow

Lake Fire, which was making repeated attacks on the canyon area before threatening Tower-Roosevelt. The Hell-roaring Fire, perhaps caused by humans, started north of the park and ran over 54,000 acres in only twenty days. Now it had entered the park.

A helicopter crewman told us of seeing a small puff of smoke just south of the park. In the minutes required to get to it with a water drop, the newly born Huck Fire had spread to hundreds of acres, forcing the evacuation of Flagg Ranch and the park's south entrance.

Firefighters made their final stand to save Silver Gate and Cooke City from the rapidly advancing Storm Creek Fire in the adjacent national forest. It felt like the whole nation was holding its breath to see what would happen next.

Fire-behavior predictions are of extreme importance to the safety of firefighters, and in the course of the summer, I had posted many of them. The one on September 7, however, stood out from all the rest:

> The fires are completely dominated by the wind under current conditions, burning day and night when the wind occurs.
>
> Traditional perimeter-control, fire-suppression strategies have not been effective.
>
> Despite strategy of attempting to control perimeters of fires, the net result has been reduced to the direct protection of life and property.
>
> We are expecting the next wind event to lead to extensive fire growth and *serious* and *immediate* threats to Cooke City, Silver Gate, West Yellowstone, Canyon Village, Old Faithful, and the Crandall/Sunlight Complex.
>
> In the foreseeable future, we will be repeating this high-pressure/cold-front cycle again.

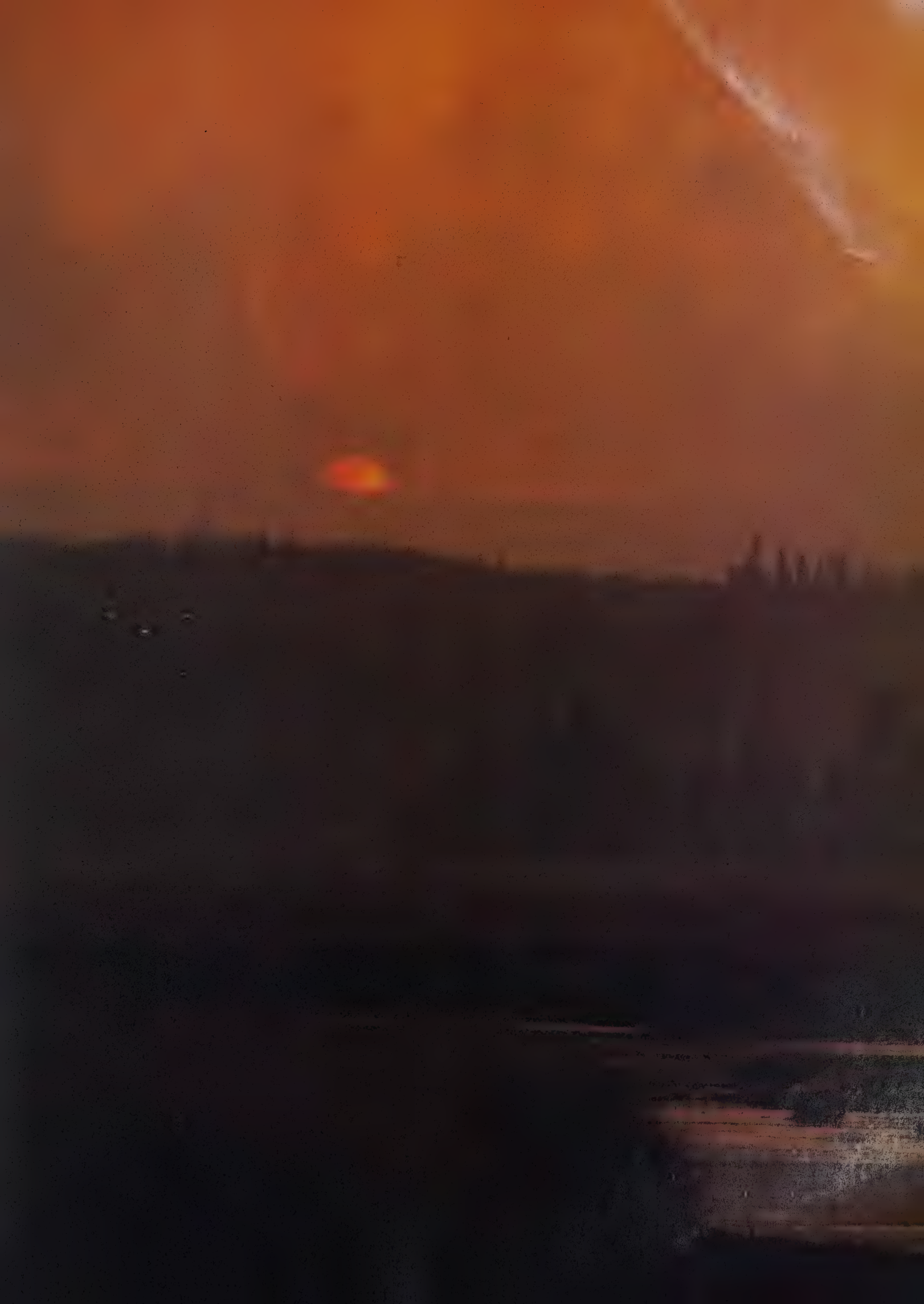
Looking up at the orange skies, we could only wait and watch and wonder.

Stories began drifting into camp: Of spot fires being stopped within a hundred feet of the Canyon Visitor Center; of the protection of the Old Faithful area in the face of a searing firestorm; and of the terrific effort of the few who defended Tower-Roosevelt. Each of these is a true tale of heroism unto itself that is best told by those who were there.

But when the smoke cleared, the villages of Old Faithful and Canyon and the communities of West Yellowstone, Cooke City, and Silver Gate were still standing. Regrettably, some cabins and sheds at Cooke City and Old Faithful had burned, but by and large, there was a great sense of relief around the park.

On September 11, it snowed. In the next days, the fire status reports continued to come through the Fire Information Office. Listed next to the names of many of the major fires were the welcome words, "70–100% contained." The fires would make their final attempts on Mammoth Hot Springs and Lake Village, but this was a moral victory. In mid-November, the park would issue a press release announcing that the fires were officially out. But in the minds of many of us here, on this day in September, the long, hot summer of 1988 was over.

Behind the ranger station a few days later, I saw a herd of deer walking in silence through the softly falling snow. The press directed their questions toward the blades of green coming up through the blackened soils. Already, the scorching memories of summer were fading into white. □



Lodgepole pines, summer 1988

The Summer We Let Wild Fire Loose

How "natural" were the fires of 1988?

by Stephen J. Pyne

> Let's all but bring to life this old volcano,
> If that is what the mountain ever was—
> And scare ourselves. Let wild fire loose we will—
> —Robert Frost, "The Bonfire"

From *The Poetry of Robert Frost*. © 1969 by Henry Holt and Co., Inc.

Everything about the fires seemed exaggerated. Groves of old-growth lodgepole pine and aging spruce fir exploded into flame like toothpicks before a blowtorch. Towering convective clouds rained down a hailstorm of ash, and firebrands even spanned the Grand Canyon of Yellowstone. Crown fires propagated at rates of up to two miles per hour, velocities unheard of for forest fuels. A smoke pall spread over the region like the prototype of a nuclear winter. Everything burned.

It was as though the ancient caldera had, as geologists have warned, rumbled to life, spewing forth geysers of flame and sending out streams of fiery lava across the plateau, obliterating everything in their path. Approximately 45 percent of Yellowstone National Park burned in some fashion, almost a million acres in all. At the fire's height, the Greater Yellowstone area spent $3 million a day and converted the park into a black hole that sucked in firefighting resources from everywhere in the country—this while officials adamantly insisted that only winter would extinguish the fires. As a display of natural power, the fire was a staggering, compelling, costly, and humbling spectacle.

But then Yellowstone encourages hyperbole. It is a huge place, populated by big animals and endowed with an immense symbolism. Like a celestial body so massive it warps space and time, Yellowstone exaggerates everything it touches and distorts perspectives around it. The fire was, to some, an ecological holocaust, nature's *Götterdämmerung*. To others, it was an eruption long predicted and much overdue, the invisible hand of nature working to correct biotic imbalances. Yellowstone's immensity—geographic and symbolic—allowed no middle ground.

The earth is a fire planet, and *Homo sapiens*, a fire creature. The earth has fire because it has life. Marine life created an oxygenated atmosphere, and terrestrial life established fuels. With lightning as a plentiful source of ignition, fire and life have coevolved. Charcoal can be found in coal-bearing strata throughout the geologic record. Wildlands everywhere—excepting the perennially wet and the perennially dry—experience fire regularly. Fire decomposes and recycles what life does not. It rearranges the structure of ecosystems, redefining and redistributing available niches, and it readjusts the rhythms of biotas. Nearly all biotas can be characterized as fire regimes, and in some ecosystems there is an extraordinary interdependence with fire.

Unlike many recent anthropogenic insults, fire is also "natural." There is an ecological precedent—even an imperative—for mammoth fires that is not true for large oil slicks or clouds of radioactive debris. Fire cannot be extirpated from the earth. To exclude it from wildland environments is not only impossible over long periods of time, it is self-defeating.

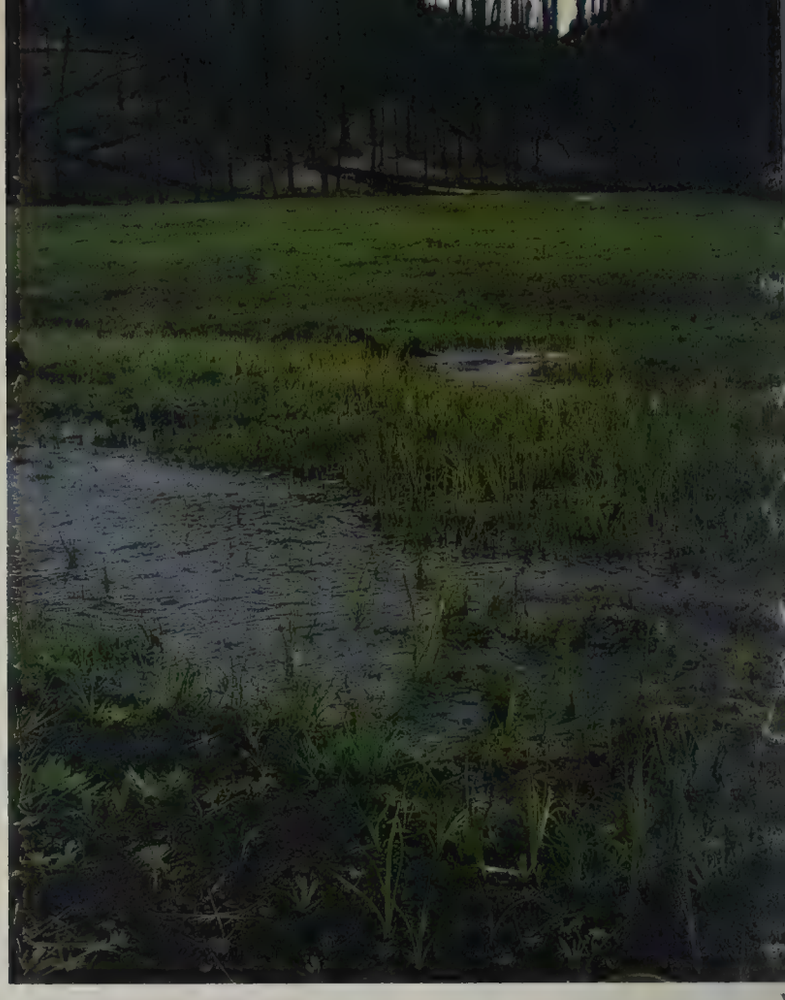
But what makes fire especially ubiquitous is its ancient alliance with humans. The dominion of fire is essentially that established in partnership with humans. While humans share with other organisms the capacity to influence fuels, *Homo* alone can control ignition. The oldest hearth now dates to 1.5 million years ago, roughly coincident with the appearance of *H. erectus*. Fire is part of our heritage as a species.

The fire regimes that now characterize the earth are by and large the outcome of the interaction between humans and natural environments. Humans have taken fire to tropical rain forests that had not, under wholly natural conditions, known it; they have removed fire from regions like the tallgrass prairie of the Midwest and the conifer forests of New England that had formerly contained it; everywhere they have reconstituted the frequency, geography, timing, intensity, and character of free-burning fire. The history of fire is inextricably intertwined with the history of humans, like the two bonded strands of a DNA molecule. To tell the natural history of fire without reference to humans makes as little sense as to tell human history without reference to fire.

When it joined humanity, fire entered a moral universe. Humans had the capacity to manipulate fire, but they did not come programmed with instructions on how to use it. How should fire be applied and withheld? By what means? For what purposes? The range of options was vast, and even subtle shifts in the environment or in fire practices could ripple throughout a biota. Many ecosystems are shaped and driven by the power of fire applied under the direction of human will. Its firepower commanded society to invent a code of fire practices to regulate its fire technologies.

By changing the way we use natural resources and the way we think about nature, the industrial revolution reformed our relationship to fire. All over the world—spearheaded by

Elk Creek in the winter after the fire, below, and the following spring, right, when the ash had been washed away.



European foresters—industrialization drove back traditional fire practices while it struggled to concoct a suitable substitute. Then, like steel on flint, new thinking during the 1960s struck inherited practices and kindled new concerns. For the National Park Service the critical document was the Leopold Report (1963), which urged the restoration of fire to wildlands; for other federal agencies, the Wilderness Act (1964) compelled them to reassess their acquired pyrophobia. Ecological arguments for preserving fire in natural areas merged with powerful ideological currents that swirled around the concept of wilderness.

The revolution soon inspired policy reforms. In 1967–68 the National Park Service released administrative guidelines that encouraged controlled burning and, by implication, the accommodation of natural fires. The Forest Service adjusted its policies in 1972, then reformulated them in 1978. "Prescribed" fire—controlled burning conducted under a specified set of conditions to meet specified goals—became the rage.

But what fire practices were suitable? Suppression was not a neutral act; it did not quick-freeze an ecosystem, which changed by having fire withheld as surely as it changed by being burned. And prescribed burning raised problems, too—escape fires were common, outcomes were not always predictable, and prescribed fire was, after all, a form of calculated intervention that left some people with the uneasy feeling that it was out of character with an untrammeled wilderness. Wildland fire is far from a precision instrument. It is not some kind of Bunsen burner that can be turned on and off at will. Starting in the mid-1970s, most of America's disastrous wildland fires resulted from breakdowns in prescribed burning. At the other end of their shovels, firefighters found something that resembled a smoking existentialism.

Gradually a consensus emerged that fire of some sort belonged in the landscape. The most spectacular fire practice of the revolution involved the co-opting of naturally ignited fires into overall fire-management plans. Initially, a naïve philosophy prevailed, which held that wilderness fire management only required the restoration of a natural process to a natural landscape. However, the fundamental need was to reconcile one hybrid of nature and culture, fire, with another hybrid, wilderness. To exclude anthropogenic fire and rely on lightning fire alone did not restore an ancient environment but created landscapes that probably had never before existed. Regardless, natural fire became the symbolic epicenter of the new age. And Yellowstone quickly declared itself the paragon of natural fire management.

Yellowstone's great asset was its size. Natural fire management means big fires. Big fires do most of the biological work; they perform in ways that smaller fires cannot replicate even in aggregate. Big fires are, for wilderness purists, the perfect symmetry of spectacle and symbol, a vestal fire in America's virgin lands. A fire program that excludes big fires is a sham. But big fires require long times and large areas. In the northern Rockies, high-intensity fires that engulf whole stands are relatively infrequent. The biota may take several centuries to arrange itself into a suitable fuel array to support such a fire, and then drought, winds, and lightning have to appear in proper sequence. Once initiated, a big fire becomes by nature a crown fire—racing through the canopy, catapulting firebrands by the thousands, some over many miles before they descend and kindle spot fires. It is uncontrollable by technology and only contained ultimately by a geography generous enough to transcend the normal spans of fuels and weather.

But more than geography alone is involved. Managing natural fires involves a complex choreography between control and use. In essence, a naturally ignited fire is accepted if it burns within a specified geographic area and according to a prescribed range of behaviors and effects. If the fire threatens to leave that

prescription, then fire organizations must either push it back into prescription or extinguish it. Thus the ability to control fires is fundamental to the concept of natural fire management. One of the precepts of the new era, however, was the belief that information could substitute for intervention, that a knowledge of fire behavior could replace traditional fire-control technology. The role of science-based models was to advise a fire organization on which fires to accept and which to suppress and to make that evaluation early enough in the cycle to allow fire suppression to be effective. To accommodate the big fires that a natural fire program requires, there had to be a healthy margin for error.

The best insurance is land. The larger the land base, the less robust the state of knowledge needs to be and the less gargantuan the resident fire-control machinery. An immense land base is precisely what Yellowstone had in abundance. Almost any fire complex could not conceivably exceed Yellowstone's capacity to absorb it. Yet since 1972, when a natural fire program was proposed, Yellowstone had had everything a natural fire program needed except, ironically, large fires. Through 1987, 235 fires had burned 34,157 acres, the largest fire reaching 7,400 acres. For a program that had loudly proclaimed its special stature, this was a pittance. The absence of large fires was an embarrassment.

At the same time, other parks and forests acquired considerable knowledge about prescribed and natural fires. Increasingly, Yellowstone fell behind national fire practices. Its once-prominent suppression organization gradually disintegrated into vestigial bits and pieces, not exactly sure of its role and shunted into other park concerns like running a helicopter. Its elaborate on-site monitoring of early fires gave way to a one-time evaluation of smoke reports, usually by aerial photos. The fire committee, which made decisions, became clubbish, haughty over its highly personalized knowledge. Yellowstone did not field a prescribed fire program: it had a let-burn program. Instead of prescriptions, it had a philosophy. Instead of control technologies, it had size. Its immensity, symbolic and political no less than geographic, insulated it from the pressures that elsewhere led to internal reform.

Then came the fires of '88. If its size had lured Yellowstone into complacency, its size also saved it from devastation. The 1988 fires went beyond the known scale of Yellowstone fire history. They were larger than any event in the history of the region's oldest trees. The impact of fires on this order is simply not known, and in the absence of knowledge, exaggeration comes easily. It has been simple, in particular, to anthropomorphize the conflagrations, to make the elk into the homeless of Yellowstone, helpless victims in desperate need of emergency shelter and soup lines. The fires were not an environmental holocaust. They burned under heterogeneous conditions and will yield heterogeneous results. The wilderness will lose no species or vital processes. But the fires will reconstitute the ecosystem in fundamental ways. They have given the biotic kaleidoscope that is Yellowstone another twist, revealing broad new patterns. The Greater Yellowstone area was, as its theorists believed, vast enough to absorb what may have been a 500-year, perhaps a 1,000-year event.

If Yellowstone had adopted the best practices, it might not have altered in any substantial way the outcome of the 1988 fire season. Its choices were limited. If suppression was to be effective, it had to be implemented very early. Yellowstone wanted big fires—it deserved big fires—and no one anticipated in the early weeks how relentless the conflagrations would become. Once that initial state passed, there was little to do but spend money and throw suppression resources at the fires.

It is not clear that Yellowstone understood, then or now, the fires' larger context. As the summer worsened, the park management continued to insist that the issue was not the fires but pyrophobia, that it was really battling to educate the public and the fire community to the ecological value of fire, that its enemy was not a smoke pall the size of Wyoming but Smokey the Bear. It repeated mantralike lines from its fire plan to the effect that "nature is amoral." It was inappropriate to apply human values to wilderness events. The invisible hand of nature, not human calculation, would dictate the outcome. Wilderness was cheapened if humans predetermined its composition and dynamics. It was unfair to judge the park for a wholly natural, amoral event.

This argument is both flawed and misplaced. Once the fires became large, they were a power no different from hurricanes or earthquakes over which humans have little control. But the park could have altered the fuel structure in advance of the outbreak, and it could have intervened when the fires were small. Park apologists have tried to deflect the failure onto fire suppression. They point out, correctly, that fire control in the contemporary mode is an aberration in the long spectrum of human and natural history. But so is the more recent concept of using natural fires to advance land-management objectives. The norm is the human use of fire everywhere and for every conceivable

Overleaf: Lodgepole pine cone and green shoot, Madison River, May 1989

A male blue grouse, left, in full display on the slopes of Mount Washburn, spring 1989. Below: A badger on a burnt sage meadow, near Mammoth Hot Springs.

purpose. Both natural fire and suppression are anomalies because they propose alternatives to anthropogenic fire. Yet Yellowstone purged this middle terrain—deliberate fire usage—as interventionist.

The mantra also avoids a fundamental question: how "natural" were the fires of 1988? They had burned after a century of unprecedented human activity at Yellowstone—not only the installation of a new set of human practices but also the abolition of ancient practices, including anthropogenic fire, that had occurred for millennia. A century of fire suppression influenced the character of the 1988 fires, but the degree of influence is difficult to spell out. Not fuels but climate dictated the overall fire complex.

Some 60 percent of the fires that swept through Yellowstone began outside the park or started from anthropogenic sources. If these fires are natural, as park officials suggest, then why is prescribed fire unnatural? If anthropogenic fires can enter the park because once within the wilderness they become "amoral," then why can't hunters? Probably it does not matter to a lodgepole pine or an elk what kills it, but it does matter to humans. The appeal to amoral nature does not remove park officials from their own moral universe. If the park does not express cultural values, then it has no reason to exist. Nature may be amoral; Yellowstone National Park is not.

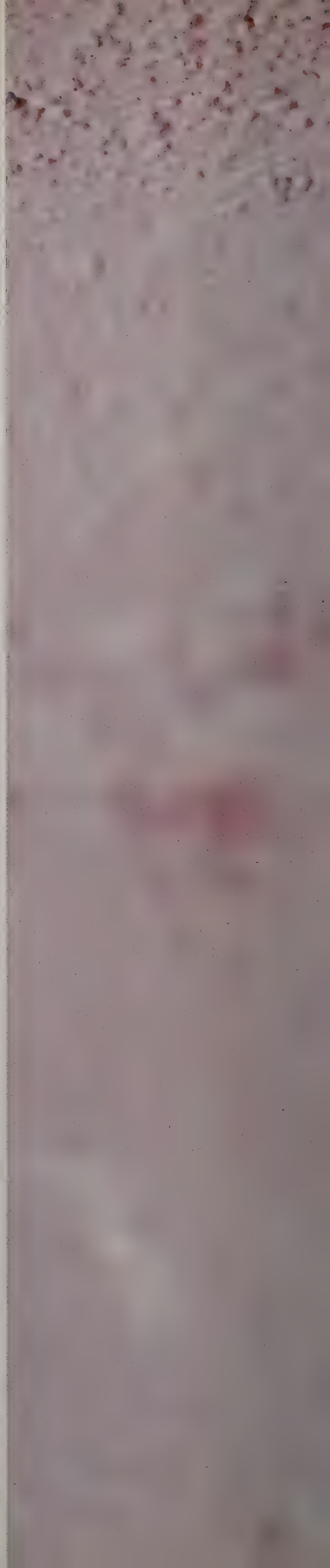
Behind this appeal to moral agnosticism lies, once again, the hugeness of Yellowstone. In a smaller or more fragmented ecosystem, intervention would be mandatory, and administrators would have to confess openly to the ends and means of their manipulation. Yellowstone, however, could cultivate its peculiar ideology in almost self-reflexive isolation—granted a bold margin for error and plentiful room for speculation, confident of its enormous importance to the National Park Service and the American public. It could, that is, until wild fire was really let loose. The great fires liberated the core issues much as crown fires seared away the waxes that held lodgepole pine seeds within their serotinous cones. In the ash bed of a million acres those questions could take root. The fires magnified almost to the point of caricature not only fire management but the whole spectrum of management concerns that plague Yellowstone.

The fires of '88 have revealed the limitations of all attempts to impose ideas on an indifferent nature. Knowledge is inevitably imperfect, technology always flawed, and the need to act ever present. What the public should demand is not complete control, which is a chimera, but a good-faith effort. It can expect the park to exploit the best practices available and to reconcile its ambitions with public opinion. The charge against Yellowstone is ultimately not ignorance, indifference, or incompetence but bad faith. It did not do what it said it was doing. It disguised its real beliefs behind a screen of agnosticism. And it refused to accept the humbling state of its ignorance.

Yet in the end those who held that Yellowstone's size was its salvation were correct. The Yellowstone ecosystem is a lot tougher than we know. Yellowstone will absorb the fires. Some of the ecosystem will recover slowly; other portions will erupt in biotic profusion. All of the burns will serve as a fascinating monument to fire ecology. The fires of '88 brought the old volcano that is Yellowstone back to life.

If the fires were exaggerated, that is the Yellowstone way. Its size took small errors, which elsewhere might have been overlooked, and leveraged them into colossal breakdowns. What might have been buried in the backcountry—as the Alaska and Bob Marshall Wilderness fires of 1988 were—roared across TV screens. That same hugeness also meant that fires that elsewhere could have consumed an entire park involved less than half of the Greater Yellowstone area. The fires proved bigger than our understanding and vaster than our technologies. They also proved larger than our egos. The biota will survive with fewer scars than will our presumptions.

As a complex, the fires burned in two swaths clustered along the northern and southern tiers of the park, sparing a broad middle corridor. In a symbolic sense, that may be what the fires do to the management of the Yellowstone environment. They may burn away the extremes and leave a less exaggerated but still robust middle. Between the burned and unburned landscapes and between the Yellowstone that existed before and after the fires, one can envision a dialectic that restructures philosophy and practice around the great middle landscape of anthropogenic fire. If Yellowstone can build on that corridor, its fire program may follow its biota into recovery, and the park in some future summer may again let wild fire loose. □



The nests of Polistes *wasps typically hang from a thin but tough stalk.*
Anthony Bannister; NHPA

Wasp Papier-mâché

Most often respected for the power of their sting, many wasps are masters of a gentler art

by Michael H. Hansell

There is a pleasing mellowness to the weathered timber of an old barn or an unpainted fence seen in the fading light of a summer evening. Run your fingers along the rounded ridges of the hard wood laid down in winters past, and the sensation is one of smoothness; running between these winter ridges are valleys of the paler, softer spring growth. Parts of the wood surface may be tinted with the colors of algae or lichens, but where the surface is bare, the wood itself seems alive, its warm color dappled with pale patches and streaks. Weathered, we say, as if rain and wind were alone responsible, but if you listen carefully in the still summer evening, you can hear the tiny sounds of the fence being broken up fiber by fiber and carried away.

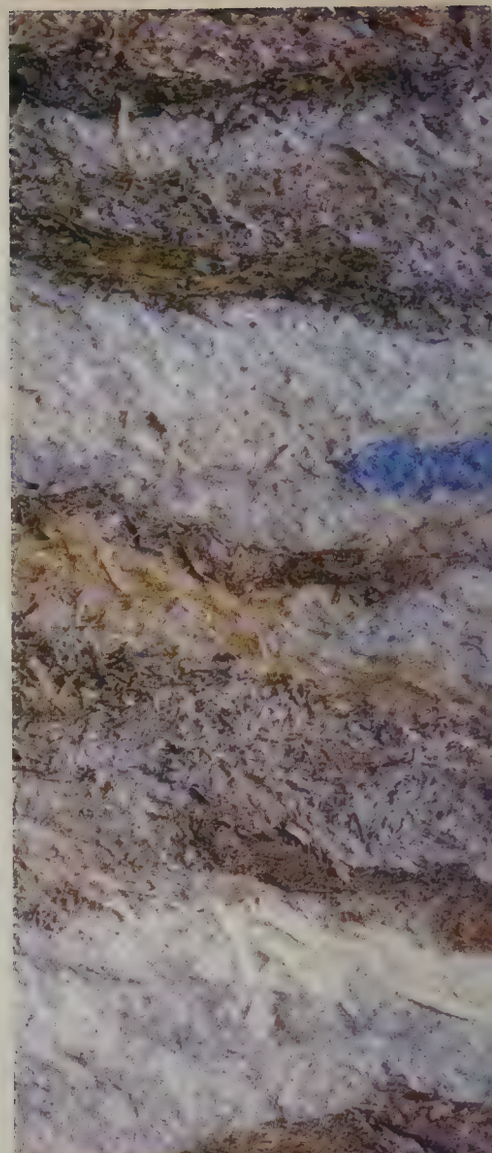
The pale streaks are very likely the fresh abrasions of wasps scraping the surface of the wood to make paper to build their nests. When a wasp is working on a thin-slatted fence, the resonance of the wood at each bite is loud enough to be heard if you are standing nearby. Bending to have a close look, you can see that the wasp rasps the wood in a particular way. Standing parallel to the grain of the timbers, it bites into the soft spring growth. After a few bites it shifts backward a little, keeping between the same two ridges of the hard winter wood. Each bite dislodges a small bundle of woody cells, which the wasp gathers into a little round pellet held in its mouthparts. After chewing on the fence strenuously for a few minutes, the wasp creates a pellet large enough to carry back to the nest. So the projection of winter growth above the valleys of soft spring wood is at least partly due to microexcavations of generations of wasps engaged in papermaking.

Nearly all of the Vespidae, or social wasps, build their nests out of paper, that is to say, chewed-up fragments of vegetation bound together with some kind of matrix secreted from the salivary glands. Only fertile females (queens) or sterile females (workers) make paper; as in all matters other than sex, male wasps are quite useless. The social wasps divide into three subfamilies. The first, Vespinae, comprises the yellowjackets and hornets. They are found throughout the northern temperate parts of the world. The second subfamily is the Polistinae, which includes *Polistes,* the so-called paper wasps. This common name unfortunately creates the mistaken impression that *Polistes* and its relatives alone make paper, so I am forced to refer to members of this subfamily as simply Polistinae. They live mainly in the tropics or subtropics.

The third subfamily of social wasps, the Stenogastrinae of tropical Asia, is much less well known. They are commonly called narrow-bodied, or hover, wasps. Abundant in forested areas of Malaysia and neighboring countries, these wasps, with their delicate, elongated abdomens, are shy, secretive, and generally small. They have been accused of being dull, but I disagree. Imagine yourself in a tropical forest clearing, the air shimmering with insect noise. Among the threads of a large spider's web, a delicate wasp, jet jeweled in amber, hovers while turning slowly to look around. It glides forward gradually, pecks a tiny dead insect out of the web, and slides away backward. The spider, gross in comparison to the wasp, tenses but is too late to attack.

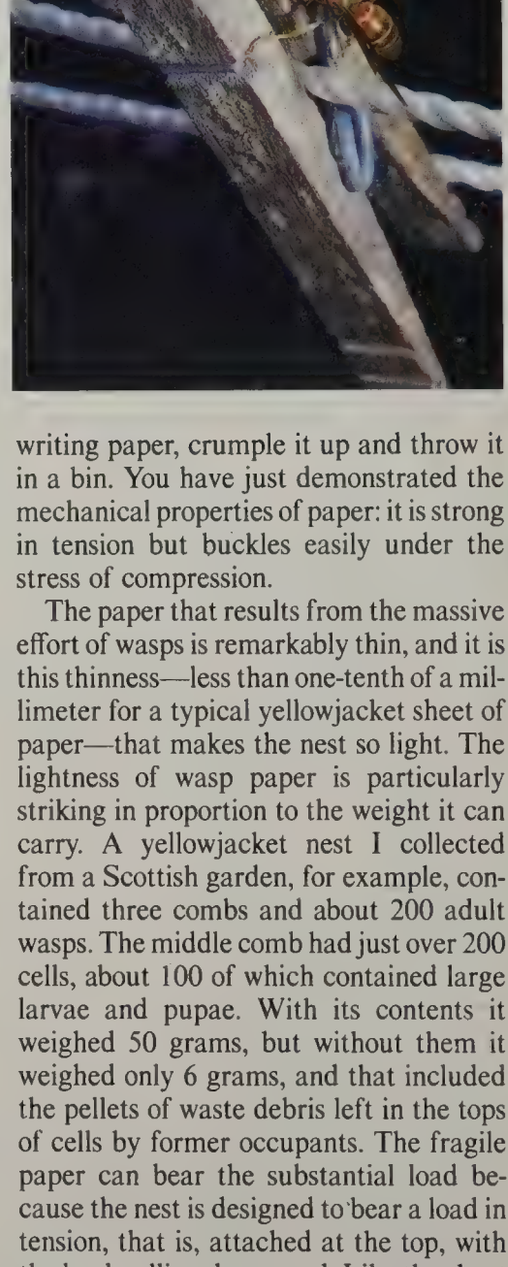
The three subfamilies—yellowjackets, Polistinae, and hover wasps—are important characters in the story of papermaking in social wasps. Differences and similarities in their biology, I believe, are related to the differences and similarities in their paper.

E. S. Ross



Lining herself up parallel to the grain of the wood, a wasp, below, scrapes off pulp for her nest. Wasps may gather pulp from many sources, as the envelope of the vespine wasp nest at right shows. Each band of color represents a single load delivered by one wasp.

Bob Gossington; Bruce Coleman Inc.



Returning to its nest with a pellet of wood pulp, the yellowjacket worker carries her contribution to the brood comb (where eggs are laid and young develop) and starts to add it to the rim of one of the comb's many hexagonal cells, working the fresh material with her jaws and spreading it gradually into a thin sheet. Scores of other workers are also out collecting wood pulp, for building is a collective effort.

Surrounding the comb of brood cells is a multilayered, protective envelope, also of paper. The envelope is extended outward by the addition of new layers, while the central cavity containing the combs can be enlarged by the removal of inner envelope layers. In some yellowjacket species, new envelope is added as small patches, the outer layer of the nest being made up of a patchwork of several hundred of them. Each patch bears a scalloped pattern of slightly different shades of gray and brown. Every band of color represents paper made from a single pellet of material brought by a wasp from the tree trunk or post it currently favors. One patch of the envelope surface may be built from ten to twenty paper loads; I calculated that one large yellowjacket nest in my collection must have required at least 200,000 loads. At its peak, up to 2,000 wasps may have belonged to this colony. As summer fades, a large colony like this dies out, leaving only young mated queens. Next spring each queen will found a colony by building a small nest with a handful of cells in its comb.

Paper is remarkable stuff. Moses would have regarded it as a great improvement on tablets of stone had he been offered a swap halfway down Mount Sinai. But lightness is not paper's only virtue: it can also be very strong. Here is a demonstration you can perform yourself. It has the merit of being convincing if it works, and of only resulting in slight expense if it goes wrong. Take a sheet of airmail paper and grip each end by pressing your fingers into the palms of your hands; this spreads the tension fairly evenly across the paper's surface. Now pull your hands outward as hard as you can. I hope you find the paper impossible to tear. When you have rendered unusable a perfectly good piece of writing paper, crumple it up and throw it in a bin. You have just demonstrated the mechanical properties of paper: it is strong in tension but buckles easily under the stress of compression.

The paper that results from the massive effort of wasps is remarkably thin, and it is this thinness—less than one-tenth of a millimeter for a typical yellowjacket sheet of paper—that makes the nest so light. The lightness of wasp paper is particularly striking in proportion to the weight it can carry. A yellowjacket nest I collected from a Scottish garden, for example, contained three combs and about 200 adult wasps. The middle comb had just over 200 cells, about 100 of which contained large larvae and pupae. With its contents it weighed 50 grams, but without them it weighed only 6 grams, and that included the pellets of waste debris left in the tops of cells by former occupants. The fragile paper can bear the substantial load because the nest is designed to bear a load in tension, that is, attached at the top, with the load pulling downward. Like the sheet of airmail paper, it produces a structure both light and strong.

Social wasps evolved from solitary ones, but none of the solitary wasps to be found today build a paper nest. For the most part they either excavate burrows or build cells of mud. In both these types of builder however, there is evidence of the evolu tionary origin of papermaking. Som mud-building species decorate the outsid of their cells with small pieces of veget tion, while others make them entirely small pieces of vegetation stuck togethe with mud and saliva. Some present-da burrowers do make a kind of paper b excavating their burrows in plant stem and separating the cells with partitions chewed-up pith.

Initially, the advantage of paper cel over mud cells or burrowing could simpl have been that they made nests cheape requiring less time and energy to buil Also, and perhaps more important, pape provided the opportunity of situating nest out of harm's way. For one princip of paper architecture is fundamental: hangs, and anything that can be hung ha an improved chance of being place where walking predators, at least, are n likely to set foot.

In the tropics, the most abundant an damaging of such predators are the ant

You can hardly place your hand on a tree trunk or hanging vine stem without disrupting the traffic of a trail of foraging ants. Hanging a nest at the very tip of a plant stem not only places the nest in a quiet cul-de-sac but also minimizes access to it. The result is a nest less likely to be located by an ant and more easy to defend from a crowd of them. Many of the species of hover wasps that I have studied in tropical Asia use this technique by placing nests at the ends of fine natural suspensions. One such site, giving shelter from the rain as well as security from ants, is the tips of fine roots exposed under the banks of streams as they cut through the forest. All of these wasps have small colonies, generally of only two to five individuals, and are consequently in a poor position to protect themselves; their best line of defense may be to be hard to reach in the first place.

The other great threat to these mild-mannered forest wasps is marauding tropical hornets. These ferocious hornets are probably ten times the weight of the average hover wasp. I once watched two diminutive female hover wasps, which I had come to know personally during weeks of observation, hovering near their nest, favoring discretion over valor, while a hornet tore out the side of a paper cell with a single grab of its jaws and dragged out the white, flaccid larva from within. When the hornet left, the tiny, undefended nest was in ruins.

As hornets hunt by sight, their effect, via natural selection, on the design of hover wasp nests has been to make them less easy to see or to recognize for what they are. The commonest adaption is a stick-mimic nest, which in its extreme form is simply a row of cells laid end to end along a fine support.

Building a nest on a fine stem or rootlet may be an effective method of minimizing ant predation, but it means that suitable nest sites are limited by the availability of such suspensions. How much more convenient if larger nests could be built anywhere, while still offering limited access for ants and other predators. This state of affairs has been achieved by the polistine wasps. *Polistes* species typically build a comb that hangs from the underside of a stem or leaf by a fine stalk, or petiole, made from the same paper recipe as the rest of the nest—plant fragments and salivary secretion.

Of course, to hang the weight of the comb, brood, and wasps from a narrow stalk requires a high-quality paper. The paper of *Polistes* species is composed typically of long, woody plant fibers bound together with rather generous amounts of salivary matrix. The thinness of the walls and the abundance of the saliva sometimes give the paper a glistening, transparent quality. These nests are tough, light, and apparently showerproof, sometimes being found in exposed sites in areas of high rainfall.

When I looked closely at the nests of hover wasps, I found a different sort of paper. Rotted, crumblike fragments of plant material were held together by only a little matrix. The result is a poor-quality paper with cell walls about three times thicker than those of any similar-sized *Polistes* species. This difference led me to think that the hover wasps' inability to construct stalks from which to suspend their brood cells is the result of a technological limitation—they simply haven't mastered the art of papermaking. The confinement of hover wasps to nest sites well sheltered from the rain also supports the notion that poor paper quality substantially reduces their choice of nest site.

I believe that the level of papermaking skills affects more than just where wasps build their nests. I think the ability of some wasps to manufacture good, strong paper contributed significantly to the evolution of social behavior in these species. A large colony of wasps requires a big nest. The universally small colonies of the hover wasps could be a result of the species' inability to produce strong enough materials for a large nest. In the Polistinae and yellowjackets, by contrast, high-quality paper was just what was needed for the construction of large nests.

The theory that hover wasp society is limited by its nest-building technology must, like any theory, be judged alongside

E. S. Ross

Yellowjacket nests, below, top, are globular, with a single small entrance hole in the outer envelope limiting access to the eggs and larvae within. Some hover wasps, below, bottom, do not build an envelope and simply lay their brood cells end to end. Right: Always alert, polistine wasps stretch themselves out menacingly when threatened.

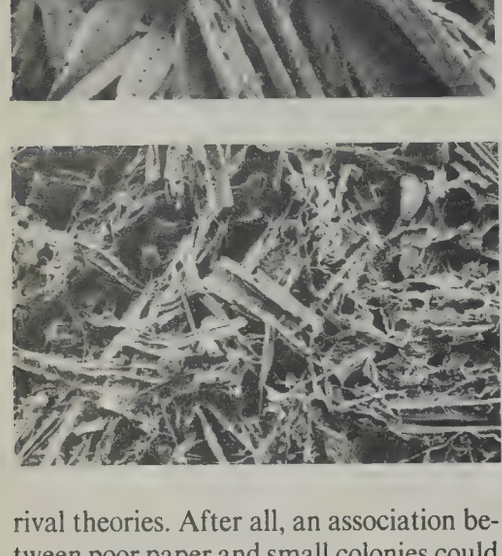
Stephen Dalton; NHPA

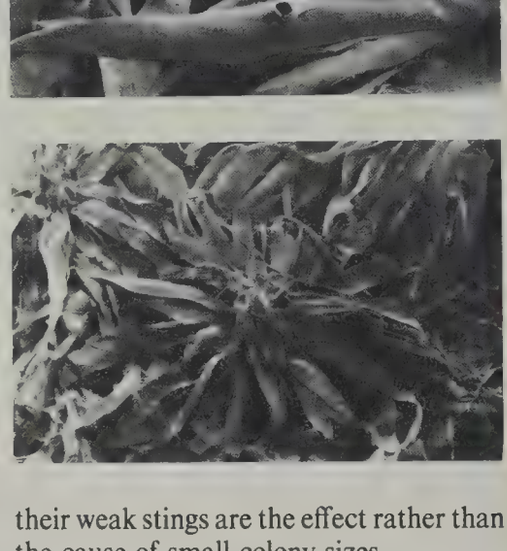
E. S. Ross

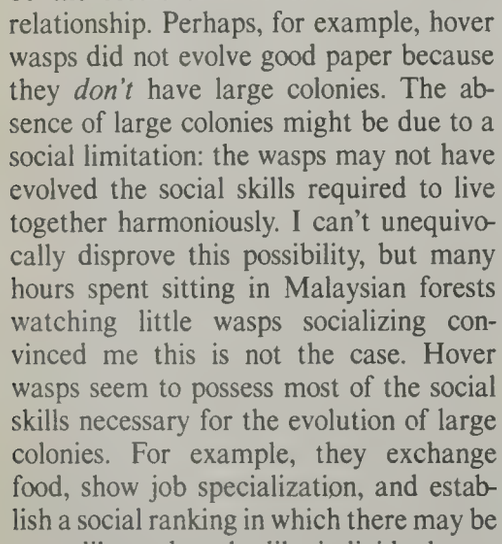
Dick J. C. Klees

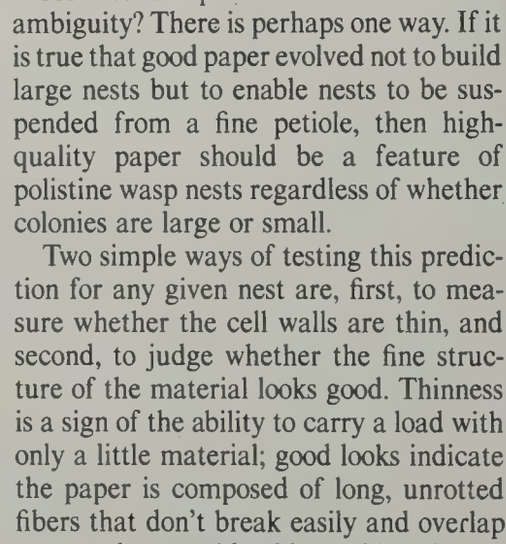
Long plant fibers, below left, from a yellowjacket nest make much better paper than do the shattered plant cell fragments, bottom left, found in a hover wasp nest. Some wasps incorporate plant hairs in their paper, such as these kayak- and flower-shaped hairs, below and bottom right. Right: One nest may contain young of all stages. Once eggs hatch, the larvae are fed by adult workers. When the larvae of some species have grown big and fat, they spin white silk caps over their cells and retire to pupate. After a couple of weeks, they emerge as adults.

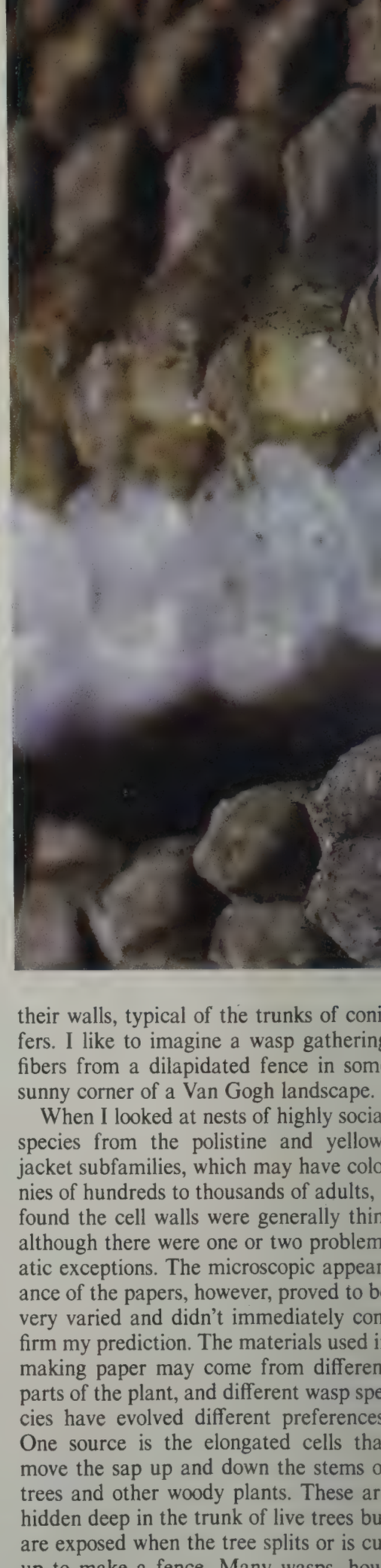
Michael H. Hansell











rival theories. After all, an association between poor paper and small colonies could be the result of a reverse cause–effect relationship. Perhaps, for example, hover wasps did not evolve good paper because they *don't* have large colonies. The absence of large colonies might be due to a social limitation: the wasps may not have evolved the social skills required to live together harmoniously. I can't unequivocally disprove this possibility, but many hours spent sitting in Malaysian forests watching little wasps socializing convinced me this is not the case. Hover wasps seem to possess most of the social skills necessary for the evolution of large colonies. For example, they exchange food, show job specialization, and establish a social ranking in which there may be queenlike and workerlike individuals.

A second possibility is that hover wasps are limited by the weakness of their stings. The argument here is that large colonies would be more conspicuous to predators but the wasps would not be well equipped to defend themselves. This theory is difficult to assess on present evidence. Hover wasps are certainly reluctant to defend themselves, and although some are as big as, or bigger than, the smaller polistine wasps, their stings appear to be weaker. But, as before, it could be maintained that their weak stings are the effect rather than the cause of small colony sizes.

How to escape this cause and effect ambiguity? There is perhaps one way. If it is true that good paper evolved not to build large nests but to enable nests to be suspended from a fine petiole, then high-quality paper should be a feature of polistine wasp nests regardless of whether colonies are large or small.

Two simple ways of testing this prediction for any given nest are, first, to measure whether the cell walls are thin, and second, to judge whether the fine structure of the material looks good. Thinness is a sign of the ability to carry a load with only a little material; good looks indicate the paper is composed of long, unrotted fibers that don't break easily and overlap one another considerably, making the paper hard to tear. Both these criteria have been met in the small nests found in the genus *Polistes* and some of its relatives that I have looked at, at least in comparison with the nest material of the hover wasp. These nests have a single comb suspended from a fine petiole, and colony size ranges from about three to thirty adult wasps. One *P. gallicus* nest I was given came from southern France. A scanning electron microscope picture of its paper shows nice long plant cells with pits on their walls, typical of the trunks of coni fers. I like to imagine a wasp gatherin fibers from a dilapidated fence in som sunny corner of a Van Gogh landscape.

When I looked at nests of highly socia species from the polistine and yellow jacket subfamilies, which may have colo nies of hundreds to thousands of adults, found the cell walls were generally thi although there were one or two problem atic exceptions. The microscopic appear ance of the papers, however, proved to b very varied and didn't immediately con firm my prediction. The materials used i making paper may come from differen parts of the plant, and different wasp spe cies have evolved different preferences One source is the elongated cells tha move the sap up and down the stems o trees and other woody plants. These ar hidden deep in the trunk of live trees bu are exposed when the tree splits or is cu up to make a fence. Many wasps, how ever, apparently get their material fro the surface layers of plant stems or pe haps leaves. This material appears in th

aper as thin scales made of a patch of quare or rectangular cells. These scales o not look as suitable for making good aper as do long stem cells, but they are learly rasped from unrotted stems, so the ndividual scales are strong and, if cemented together with a good supply of alivary matrix, make a strong paper.

Most interesting-looking papers come rom yet another source—leaf and stem airs. The hairs on plants serve either to ut down water loss or deter insect plantaters. Some of the smaller, highly social olistine wasp species have discovered hat these hairs make good building materal. Among the better known are members of the genus *Apoica*. These wasps are nusual for being nocturnal, but their ests are something of a curiosity as well. he shape of the nest is a simple comb, ith a thick top and brood cells composed f a loose, spongy mass of plant hairs. On xamining an *Apoica* nest sent to me by a olleague, I discovered that it was comosed of hairs of two different types: long, hin ones, coming to a fine point at the tip, and wavy ones, pointed at both ends. The latter posed a bit of a problem as to how they had been attached to the leaf, until I noticed that some of them had a fine stalk emerging from the middle.

The discovery solved another problem for me—the identity of structures that were the sole component of the paper from the nest of a small wasp I had examined in the British Museum collection. These structures looked like nothing so much as minute Eskimo kayaks with an entrance hole in the middle at the top of a short turret. These, too, I decided must be double-ended plant hairs that attach to the leaf by a short, narrow stalk. The most elaborate hairs of plants are branched or multipointed; these can also be found in the paper of some wasps. I managed to baffle the botanists in my own university with a polistine nest material largely composed of what looked like many-petaled flowers, except that they were only a quarter of a millimeter in diameter.

But plant fragments alone do not make a wasp's nest; salivary secretions are essential as well. This binding matrix can also vary among species and at present claims its own mysteries. We do not yet know much about its composition and are even uncertain as to where it comes from. Wasps have glands in the head and in the thorax, all of which lead to the mouthparts, but we have no idea which gland or glands produce the matrix.

The contribution of the matrix to the nature of the paper can be small or great. The papers of the narrow-bodied wasps have very little matrix in them, another reason for their poor quality. In contrast, some papers made by polistine wasps have so much matrix that the plant fibers are completely embedded in it, like glass fibers in the resin of a boat hull. In two species—one from Southeast Asia and one from South America—the nest envelope is composed entirely of matrix and resembles a fine polyethylene membrane.

The evolution from small colonies to large ones brought with it a change in the purpose of the nest. There were fewer places to conceal the nest but increased

A yellowjacket worker adds to the envelope of her nest. In this genus of vespine wasp, envelopes are scalloped, hilly affairs, each little covered pocket of air contributing to the nest's insulation.
K. Richter

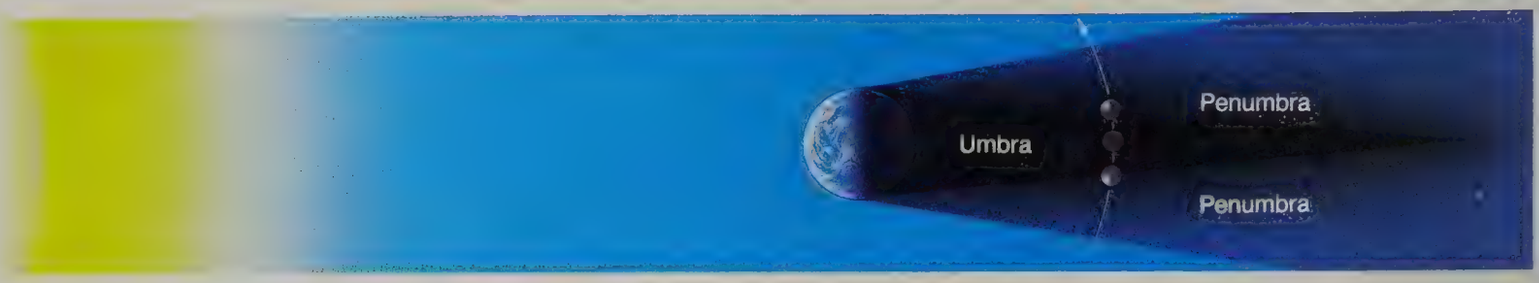
potential for mounting an effective collective defense. Consequently, the priorities in nest design changed. An elongate nest disperses defense. The smallest defendable surface can be achieved with a spherical nest. Nests like this were easier for predators to locate, but access to the brood could be limited by building an envelope to surround the comb, with access hardly bigger than the size of a wasp. The shape of large wasp nests in the tropics seems to have been dictated by such concerns. Cells are aggregated into combs; combs may then be stacked one upon the other to create a more or less spherical structure. The combs are often enveloped in a tough paper skin with one or a few access holes where defense can be concentrated.

For yellowjackets and hornets, with their mainly temperate distribution, climate was probably more important than predation in shaping the architecture of the nest. But since the most effective way to conserve heat in the nest was to reduce surface area and insulate the walls, this, too, led to spherical nests with stacked combs. The nest envelope, however, instead of being a single tough wall, became rather like flaky pastry: many layers with insulating air trapped between them.

In yellowjacket nests, the collection of combs into a stack has required a new architecture in which the bottom of each comb is linked to the nest by a scattered arrangement of what might be called pillars. But in saying this I am being human-centered, as well as utterly misleading. To say *stacked* implies one *above* the other, whereas the original comb is the top one and the subsequent combs are hung below, not by pillars, but by tension struts. So although the architecture is new, the technology is the same. Thin sheets of paper are molded into combs of hexagonal cells, and the struts linking the combs are the descendants of the nest petioles of small-colony ancestors.

We regard wasps as fierce predators of other insects, and rightly so. We admire them for their bold, tiger colors, and we fear their injections. But we should not forget, the next time we notice the dappled colors of a garden fence, to also praise them as crafters of paper. □

Copper Moon

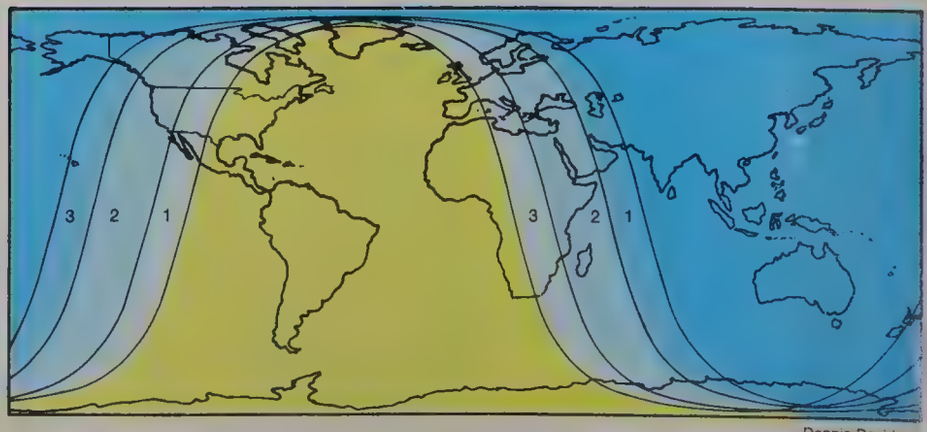


On August 16, a total lunar eclipse, above, will be visible from eastern North America. The moon passes through the penumbra (a partial shadow that will not visibly dim the moon) and enters the umbra (the earth's dark shadow cone) at 9:21 P.M. EDT. The moon is completely eclipsed by 10:20 P.M. and travels through the umbra, emerging at 11:57 P.M. The moon appears full again in the penumbra by 12:56 A.M. (Be sure to adjust for different time zones.)

The progress of the eclipse is shown for eastern North America. During the event, the earth's shadow (the dark circle, not actually visible in the sky) and the moon move upward to the right as a result of the earth's rotation. But the moon passes through the shadow from right to left because its orbit around the earth carries it eastward (left).

The moon darkens appreciably during the eclipse but remains visible because some sunlight is refracted around the edge of the earth. Because blue light is absorbed by the earth's atmosphere, only red light is refracted onto the moon, giving it a coppery color. Light variation from one eclipse to the next is determined by the amount of clouds and dust (from volcanic ash or pollutants) in our atmosphere; more clouds and dust produce darker, redder eclipses. During this eclipse, the moon will pass almost through the center of the earth's shadow (where it will be its deepest red), extending totality to one hour thirty-seven minutes, near the maximum duration of one hour forty-five minutes.

The entire eclipse is visible everywhere in the central yellow area. In the blue-shaded areas of North America, however, part of the eclipse takes place at or before moonrise: in area 1 the moon rises just as the eclipse begins; in area 2 the moon rises fully eclipsed; and in area 3 it rises after the total eclipse ends, but the moon is still partly in the umbra. In Europe and Africa the eclipse occurs in the morning, as the moon sets; in area 1 the moon sets before the total eclipse begins; in area 2 it sets during totality; and in area 3 the moon sets after the total eclipse ends but before the moon leaves the umbra.



Dennis Davidson

by Thomas D. Nicholson

August 1: New moon is at 12:06 P.M., EDT. Jupiter is a bright morning "star" in the east before sunrise. Venus is a brilliant evening "star," rather prominent in the dusk even though it is low in the sky.

August 3–5: The moon; the planets Mercury, Venus, and Mars; and the bright star Regulus are gathered in a tight group in Leo, close to the western horizon at dusk. We may see the moon as early as the 3d, easily by the 4th. Venus is above the moon on the 3d and to its right on the 4th. Mercury, Mars, and Regulus are to the right of the moon on the 3d and set in the early evening twilight. On August 5, Mercury passes extremely close to Mars, so with the unaided eye the planets will appear to merge. Binoculars will help in observing this gathering.

August 6–7: The crescent moon increases in prominence nightly, creeping up on Virgo's bright star Spica and passing it on the 7th after apogee (farthest from earth), which occurs about 11:00 A.M., EDT.

August 9: First-quarter moon, at 1:28 P.M., EDT, is in Libra.

August 10–11: On the 10th, Scorpius' bright star Antares is to the left of the moon in the south as they appear in the dusk. The moon moves to Antares' left on the 11th after occulting the star in the Eastern Hemisphere earlier in the day.

August 12–13: The best meteor display of the year, the Perseid shower (believed to be debris from comet Swift-Tuttle), is at maximum this morning. Its meteors, fifty or more per hour at maximum and twenty-five or more for several days before and after, are often bright and sometimes sputter or flash as they cross the sky. For the best viewing, watch from 2:00 A.M. until dawn; moonlight is not a problem this year. Look for Sagittarius around the waxing gibbous moon, near the Teapot's spout on the 12th and its handle on the 13th. Saturn is the bright object above and to the right of the moon.

August 14–16: The moon moves into Capricornus on the 14th, leaving it on the 16th, when the moon is full at 11:07 P.M., EDT. The best total lunar eclipse in several years occurs in the early evening throughout most of North America.

August 19: Perigee moon is at 8:00 A.M., EDT.

August 21: The waning gibbous moon moves out of Pisces and into Aries, the Ram, whose two brightest stars, Hamal and Sheratan, are above the moon.

August 23: Last-quarter moon is at 2:40 P.M., EDT. The lunar scene shifts to the morning sky, where the waning crescent highlights Jupiter and the stars of Taurus and Gemini for the next several mornings.

August 24–25: Taurus' orange-hued star, Aldebaran, is below the moon on the 24th and to its right on the 25th from moonrise until dawn. Brilliant Jupiter rises after the moon and to its left, and Gemini's twin stars, Pollux and Castor, are still farther left.

August 26–27: The crescent moon rises just after midnight on the 26th in Gemini and is at its closest to Jupiter that morning. By the 27th, the moon is farther to Jupiter's left and closer to Pollux and Castor, which appear one above the other, low in the northeast.

August 28: Probably our last view of the moon before it begins a new phasing cycle.

August 29: Mercury is at greatest easterly (evening) elongation, although poorly placed—too close to the horizon—for Northern Hemisphere viewers.

August 31: New moon is at 1:44 A.M., EDT. At that moment, the tip of the moon's shadow is only about 815 miles above the southern Indian Ocean. Its penumbra, or partial shadow, however, produces a partial solar eclipse over the Indian Ocean and adjacent Africa, Madagascar, and Antarctica.

Editor's Note: The Sky Map in the July issue shows the evening stars and constellations for this month and gives the dates and times for use.

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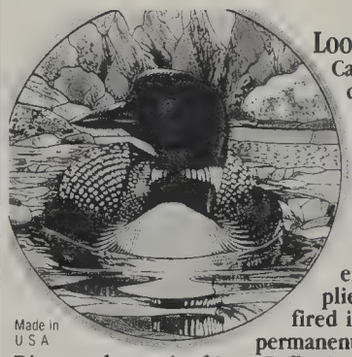
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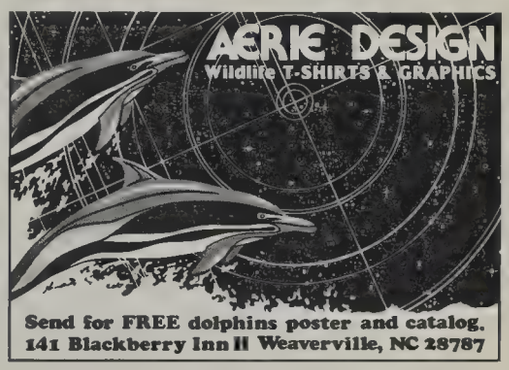

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Paint Rock, North Carolina

by Robert H. Mohlenbrock

From its origin in southern North Carolina, the French Broad River flows northwest, joining the Holston River at the eastern edge of Knoxville, Tennessee, to form the Tennessee River. On its tortuous journey, it winds through territory of both North Carolina's Pisgah National Forest and Tennessee's Cherokee National Forest. Just where the river crosses state lines, in the Unaka Mountains, a bright sandstone bluff rises seventy feet above the north bank. This conspicuous landmark is Paint Rock; the boundary between the two states runs from the shore and up along its sharp east–west ridge.

While the bluff south of the ridge is bare, the north-facing slope, on the Tennessee side of the border, supports a dense, shady forest of hemlock, red oak, tulip tree, striped maple, and many other species. In the understory are myriad wildflowers, many of which display vivid colors during the spring.

The crest itself, which is flat enough for walking, is strewn with hundreds of loose boulders. This exposed area supports a community of plants, including Virginia pine and rock chestnut oak, that grow well under very dry conditions. Because of the limited moisture, these trees grow no more

Joe LeMonnier

Paint Rock

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Paint Rock, North Carolina, above French Broad River
David Ulmer

than twenty feet tall and are spaced fairly far apart. As a result, sunlight strikes the ground virtually unimpeded, limiting the understory to a sparse community of grasses, scattered wildflowers, and crinkly reindeer lichens. At its western end, however, where the ridge slopes down to the river, there is more shade and soil. Sugar maples and Carolina buckthorns grow here, with bladdernuts filling in the shrub layer. Blue-flowered phacelias and yellow trilliums bloom here in the spring. Notable for its seemingly wilted leaves is the clammy-leaved cup plant.

In 1816 pioneer botanist Thomas Nuttall traversed the north side of the French Broad River, collecting plant specimens as he proceeded past Paint Rock. One of the plants he collected was a spindly shrub with pale green leaves. He recognized his find as a species of parasitic plant new to science, but felt it belonged to an existing genus. In 1843 botanist Samuel B. Buckley, exploring the crest of Paint Rock, rediscovered Nuttall's shrub and, intrigued by it, sent a specimen to John Torrey, a prominent New York botanist. Torrey named the plant *Buckleya distichophylla*, creating a new genus within the family of parasitic flowering plants known as the Santalaceae, or bastard toadflax family.

Botanists have since discovered that Paint Rock and its immediate area are home to a number of plant species rare for this part of Tennessee and North Carolina, and that among them, *Buckleya distichophylla*—or piratebush as it has come to be known—is one of the rarest plants in the world. Populations are known only in North Carolina, Tennessee, and Virginia, and specifics of the plant's method of growth are still incompletely understood.

In a recent study, botanist Thomas Mowbray found that piratebush tolerates great variations in moisture, being found anywhere from the banks of streams to dry ridgetops, but is intolerant of shade. All the plants identified in the wild are established either under a very open canopy or in openings created by rocks and cliffs. The largest and healthiest specimens are located in areas receiving the most direct sunlight.

The obvious feature of the piratebush is the pale green of its leaves, a sign that they contain less chlorophyll than those of most flowering plants. Photosynthesis supplies only part of the nutritional needs of the plant; the remainder comes from parasitizing other species. Beneath the ground, the piratebush puts forth structures, known as haustoria, that attach themselves to the roots of other kinds of plants and draw off nutrients from them.

For 150 years after Nuttall's discovery, botanists thought that the survival of the piratebush depended on its making connections with hemlock trees, since it usually is found in their vicinity. But in 1965, botanist Martin Piehl observed that in nature, the piratebush may attach itself to a number of different woody and herbaceous plants. In addition, botanist Lytton Musselman and forester William Mann, Jr., experimented by planting piratebush fruits in pots by themselves and with each of nineteen different species of trees. After five months, they found that haustoria of the piratebushes had made successful connections with every tree species tested except the tulip tree. They also discovered that piratebush seedlings had developed and survived without making any connections with other plants, so that at least in its early stages of growth, the piratebush can be self-sufficient.

Why the piratebush is so rare, even though there are many open, rocky habitats throughout the Appalachians, continues to puzzle scientists. William Carvel and Hardy Eshbaugh, of Miami University, have noted that piratebush grows most successfully in association with hemlocks and that it also requires direct sunlight, a combination of conditions not commonly available. They also speculate that the plant's pattern of seed dispersal and germination (concerning which little is known) may not enable piratebush to spread to isolated spots where it might otherwise survive.

"This Land" highlights the biological phenomena of the 154 U. S. national forests. Robert H. Mohlenbrock is Distinguished Professor of Botany at Southern Illinois University at Carbondale.

Wayne Irvin

Piratebush, first discovered at Paint Rock, is one of the rarest plants in the world. Right: Yellow poplar, or tulip tree

At the American Museum

Naturemax Festival

A giant-screen film festival will be held in the Naturemax Theater on Saturday, August 26, and Sunday, August 27. Beginning at 10:30 A.M. each day, films will be shown every hour on the half hour. In the Naturemax format, 70-mm film is turned on its side to create an image ten times the size of a standard 35-mm frame. The image is projected onto a four-story screen, New York City's largest. Among the twenty-four films to be shown are *The Dream is Alive*, *Living Planet*, *To Fly*, and *Great Barrier Reef*. For more information call (212) 769-5200.

Palms and Pomegranates

"Palms and Pomegranates: Traditional Dress of Saudi Arabia," an exhibition of clothing currently on display in Gallery 77, presents some thirty costumes, along with a selection of artifacts representing the traditional Saudi Arabian way of life. Palms and pomegranates are traditional embroidery motifs symbolizing friendship, hospitality, growth, and the fruits of heaven.

The climates and cultures of the Arabian peninsula are reflected in its wide variety of dress. The basic garment for both men and women is the *thawb*, a loose-fitting, ankle-length caftan. Several examples from the 1930s incorporate embroidered trains and airplanes into traditional designs.

Palm fronds are woven into hats, fans, sandals, baskets, and mats. Selections of weaponry, the silver jewelry worn by Bedouin women, and the paraphernalia of the coffee ceremony round out the exhibition.

Many of the elaborate women's costumes are rarely seen in public, since they are usually covered by a long outer cloak or *abaaya*. Most of the clothing on display is from the collection of Princess Haifa bint Faisal. The costumes in the exhibition—previously shown in Cambridge, Canton, Seattle, Los Angeles, San Antonio, and Jacksonville—will form the core collection of a museum to be built in Riyadh, the capital of Saudi Arabia.

These events take place at the American Museum of Natural History, located on Central Park West at 79th Street in New York City. For more information about the Museum, call (212) 769-5100.

Headcloths, decorated with appliqué and embroidered with silver beads, are worn in Saudi Arabia's mountainous Asir region. Paul Rocheleau

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Conservation in the USSR

by David E. Powell

"We have simply been violating nature," Mikhail Gorbachev told a conference of agricultural specialists in Moscow early this year. Clearly, their profligate attitude toward the environment has caught up with the political and economic authorities in the USSR. All the awfulness of "progress"—pollution of the air and water, an excess of pesticides and herbicides, the destruction of wilderness areas, the disappearance or imperiling of various animal and plant species—has struck the Soviet Union with the same intensity experienced in the United States, Western Europe, and Japan.

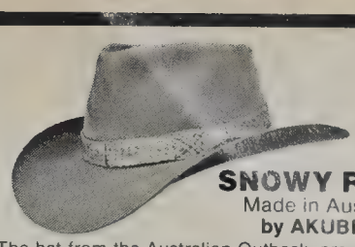
This circumstance, deeply troublesome in its own right, is all the more sad when one considers the opportunities available to Russia's postrevolutionary rulers. Indeed, we might have expected the Soviet Union to be preeminently suited to preserving and enhancing nature's gifts. It is less advanced than the West and thus can profit from our mistakes. Furthermore, the Soviet political elite has always claimed to be guided by the lofty ideals of socialist humanism. The Communist Party, the "leading core and guiding nucleus" of all organizations, is capable of enforcing its will on any problem facing the country. And finally, the Russia that Lenin and his colleagues "inherited" in 1917 had a well-developed and articulate cadre of conservationists who could point the way to balanced growth.

But this did not happen. In his beautifully written book, *Models of Nature,* Douglas Weiner chronicles the fate of Russia's conservation movement during the first fifteen years of Communist rule—the era of Lenin and the period of Stalin's ascent to power. With a fine mixture of compassion and scholarly detachment, Weiner rescues from oblivion a number of fascinating individuals who understood that nature is far more powerful than any political or economic force. Much of what one finds in *Models of Nature* could be usefully integrated into the intellectual armamentarium of the most contemporary ecologically minded person.

The hero of Weiner's tale is Grigorii Kozhevnikov, a Moscow zoologist who recognized the grave danger that economic development posed to his country's flora and fauna. Although he worked well into the postrevolutionary era, Kozhevnikov issued a fateful warning in 1908, almost a decade before the fall of the Romanov dynasty: "If we do not carry out special measures to preserve virgin nature, it will disappear entirely, and the nature transformed by civilization which will replace it will only deceive us by its one-sided luxuriance."

Kozhevnikov wrote in apocalyptic terms, warning about the possibility of ecological collapse. As Weiner notes, he was anxious "not so much about the survival of [specific] life forms for their own sake as about the consequences for civilization that a breakdown in natural ecosystems might bring." In this sense, Kozhevnikov's argument has a remarkably modern ring. It should be familiar to anyone concerned about the destruction of the Amazonian rain forest, oil spills occurring anywhere from Alaska to Antarctica, endangered and vanishing species, and the issue of ozone depletion and the greenhouse effect.

A second advocate of environmentalism resuscitated in this volume is Veniamin Semenov-tian-shanskii, president of the Russian Entomological Society. Industrial man, he wrote in 1919, was a "geological parvenu [who was] disrupting the harmony of nature's picture . . . that grand tableau which serves as the inspiration [for] the arts: music, painting, sculpture, and architecture." This scientist likened society's moral obligation toward nature to "the son's duty to his mother" and prophesied that mankind, like some character in a classical Greek drama, eventually would be punished for its hubris. "In snuffing out the hearth of Nature's life, in plundering and squandering her basic stock," he asserted, "we are



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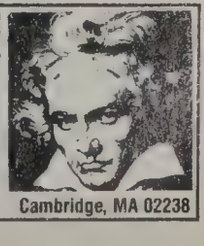

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digging our own graves, preparing a miserable future for our progeny."

Weiner also recalls for the reader some of the less enlightened voices from Russia's past. Some of these individuals were simply ignorant and prejudiced. They argued that because unmanaged nature preserves would provide a haven for predators, agricultural pests, and other "harmful" species, such creatures ought to be eliminated. Others were dangerously misinformed, vigorously calling for the "conquering" of nature in order to achieve rapid rates of economic growth. Propelled by the logic of "socialist construction," they dismissed the protection of nature as misguided sentimentalism. Conservationists, they said, should join the nationwide effort to maximize nature's productive capacity and thereby promote economic development.

The ecological movement in Soviet Russia was never very secure. In a way, the opposing forces—ignorance, indifference, greed, and politics—were not unlike those prevailing in other cultures. But under Stalin's reign, political and intellectual conflict often had murderous results. The pressure of five-year plans and demands for a "revolutionary transformation of nature" made it inevitable that the country's environment would be severely damaged. A 1931 *Pravda* article dismissed conservationists as people "striving to save . . . nature . . . from the Five-Year Plan." By the end of the 1930s, most of the nation's leading ecologists were excoriated as "reactionaries," "counterrevolutionaries," "wreckers," and "mongrels of human society." The lucky ones were merely denounced; others were sent to labor camps in Siberia and the Far North, and some were even executed for their "crimes."

Today, the world watches with fascination as Mikhail Gorbachev attempts to rouse his country from the excesses of the Stalin era and the stagnation of the Brezhnev period. Among the most serious problems facing the new leadership, one which *glasnost* allows us to discuss authoritatively, is the massive damage done to the environment during the seventy-two years of Communist rule. Hundreds of Soviet books and articles have been published in recent years, all devoted to this theme. The land has suffered, as has the air above it and the rivers, lakes, and seas that traverse it or define its boundaries.

The point here is not to make an invidious comparison between socialism and capitalism; both systems have shown themselves capable of despoiling nature on a grand scale. But most of us are familiar only with our own "achievements" in this sphere, such as acid rain, toxic waste, and littered roadways. What of our brethren in the world's first socialist state?

The General Secretary himself has spoken of the great harm done to the land. Addressing the Party's Central Committee in March 1989, he observed that during the past twenty-five years, 54 million acres of developed plowland were lost. Of this, 30 million acres were given over to industrial construction and roads; the rest, including some of the most fertile meadows and pastures, was abandoned or disappeared beneath what he termed "poorly thought-out projects" for dams, reservoirs, and hydroelectric power stations.

Authoritative Soviet spokesmen also acknowledge the parlous state of the country's air and water. Evgeny Chazov, the USSR Minister of Health, declared that air-pollution levels in 104 Soviet cities were so high that they threatened the lives of the cities' inhabitants. In addition, both official and unofficial groups interested in ecology have linked pollutants from industrial plants with diseases of the respiratory, cardiovascular, and digestive systems, as well as with a dramatic increase in birth defects. In industrial districts and in districts adjacent to the nuclear power station in the Armenian city of Yerevan, fully half of all children are born with congenital defects (physical and/or mental), are stillborn, or die within forty days of birth. And in the Ukrainian city of Khmelnitskii, the air is so badly fouled that thousands of families have been issued gas masks by the military to protect them from "dangerous" fumes.

MODELS OF NATURE: ECOLOGY, CONSERVATION AND CULTURAL REVOLUTION IN SOVIET RUSSIA, by Douglas Weiner. *Indiana University Press, $35.00; 312 pp., illus.*

What of the nation's waterways? Constantly assaulted by industry and agriculture, and given little protection by their nominal custodian (the Ministry of Land Reclamation and Water Resources), they were described in a recent *Izvestia* article as "having been reduced to a lamentable condition." The press speaks openly about "the groans of the Volga"; the Amu Darya has been described as "little more than a sewage ditch"; and other rivers are said to have undergone "ecological pillaging of vast proportions." The problems of Lake Baikal, the Aral Sea, the Baltic Sea, and other bodies of water are probably familiar to readers of *Natural History*. They have also been the subject of numerous investigations, proclamations, warnings, and cleanup programs. Still, the Central

Committee recently had to condemn agricultural and industrial officials for their "negligent and wasteful attitude toward water resources." Its resolution noted that little effort had been made to introduce "low-waste, waste-free or water-saving technologies."

Why has this happened, and what is Mr. Gorbachev doing to change it? One major culprit has been the Party's fidelity to Marxist ideology. Land and water are free goods, which means that an enterprise may use—or waste—them free of charge. Because no one has a material interest in economizing on their use, enterprise managers and ordinary citizens alike are cavalier about using them. As a leading Soviet scientist has remarked, "Until ecology is included in our society's income and expenditure accounts, it [society] will sustain a loss."

A second factor is the one that Weiner describes so well—the almost pathological fixation on meeting production quotas. Thane Gustafson, in his *Reform in Soviet Politics,* put the matter succinctly: "Enforcement of pollution control is not allowed to interfere with the fulfillment of high-priority output targets or with local employment." State agencies invariably allocate insufficient funds to industrial enterprises for antipollution purposes, while plant managers often choose not to spend the funds allocated to them, diverting resources to production shops instead. Enterprise officials strive to achieve high production indexes per ruble of capital invested; they often succeed by delaying construction work on purification installations.

How much change can one expect in view of Gorbachev's demand for "new thinking"? To date, there have been three shifts, any or all of which may benefit the environment.

The creation in January 1988 of *Goskompriroda* (the USSR State Committee for Environmental Protection) gives some reason for hope. This agency has the right to prohibit the construction, repair, or expansion of ecologically harmful production facilities and to stop the work of enterprises that "flagrantly violate the norms and rules of environmental protection." Whether or not it will exercise this right remains to be seen.

In addition, ceilings for water consumption by individual enterprises are supposed to be introduced this year, and charges for the use of water are to be applied in 1991. Here, too, everything will depend on the determination of top political leaders. There already exists a system of fines, but these were set so low that they have failed to exert much of an influence on the industrial community. Whether the new charges are substantial or nominal will determine how effective the new regulations will be in preventing or limiting ecological damage.

The final change is, potentially, the most dramatic of all. The "unofficial" groups mentioned above have led to genuine citizen involvement in ecological (and other) issues for the first time in many decades. Scientific meetings, petitions, protests, environmental organizations, and a wide range of other popular initiatives have appeared in the USSR—with the approval of the Communist Party. Since the Chernobyl explosion, official *glasnost* has combined with citizen action to force changes in the sphere of nuclear power, air pollution, water pollution, and land-use policy. Here, one suspects, is the Soviet Union's best chance for environmental protection. One can only wish Mr. Gorbachev luck as he attempts to carry out his astonishing revolution.

David E. Powell is a fellow at the Russian Research Center and a lecturer on government, both at Harvard University.

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Before the Conquest

Thousands of "Mexican" dishes could not have existed before Cortés

by Raymond Sokolov

Every time we eat a meal, no matter how banal the dishes, we carry on a historical process that has been ramifying from one end of the earth to the other since the first howling savage of our species put the first handful of solid food in his hopeful mouth. We like to think there has been progress since then, from those first hasty snatchings of grubs from the ground to the most elegant, polycultural, microwaved refinements of today's *nouvelles cuisines*. But the catch-as-catch-can days of the hunter-gatherers subtend every soufflé, every ornate mannerism on the most hyperurban menus.

Tomato salad is not, at first glance, a complex dish. Take a tomato, trim it, slic it, arrange the slices on a plate, and dres with vinaigrette. It was this extreme tech nical simplicity that attracted the Frenc newspaper food writer who calls himsel La Reynière (after the first major foo journalist, the early nineteenth century e centric Grimod de la Reynière). H slipped around France ordering *salade d tomates* in various places of note, compar ing his experiences and using this basi concoction as a gauge of the seriousness o each restaurant. And by paying attentio to such niceties as the freshness of th tomato, the precision of cutting, the ar rangement of the slices, the balance o

Feast scene from the General History of the Things of New Spain, *by Fray Bernardino de Sahagún*

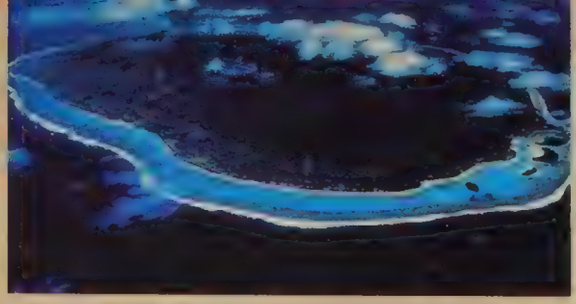
Paso y Troncoso edition o the Florentine Codex, 1905–07

flavors in the vinaigrette, and so on, almost any careful person could find a lot to think about while eating tomato salad. Let's call this the gourmet approach. It has much to recommend it; the intelligent appreciation of any dish and any meal is impossible without it and always has been. Even the hypothetical howling savage of my first example must quickly have evolved a working standard for good grub(s).

But the howling savage's children (indeed, even the HS himself, in the fullness of time) would have also approached each new meal with another set of criteria. They would have been able to relate today's grub to yesterday's. For them, isolated in time and place, preliterate, even preliterary except in the most rudimentary sense, the historical implications of a meal would have been limited to anecdotal associations and a small number of culinary variations. Millennia later, for us every mouthful is a potential for the most intense historical contemplation.

Tomato salad takes us back in time to the dawn of human settlement in the river valleys of what is now coastal Peru. Wild tomatoes were growing there, berry size and green. No records have survived of their cultivation, but by the sixteenth century, red fruits roughly comparable to the tomato so scrutinized by La Reynière were readily available in Mexico. The Aztecs, however, basically lacked oil, so that our tomato salad waited on the Spanish galleons that brought the first tomatoes to olive-rich Seville. Or it may be that this fateful encounter of Mediterranean olive and Pacific tomato occurred at a conquistador's table in Mexico, when one of the regular supply shipments from the *madre patria* arrived in the capital of New Spain with olive oil arduously dragged and toted overland from the port of Veracruz on the Gulf of Mexico.

This same commerce brought dairy animals from Europe, making thousands of dishes now thought of as authentically Mexican possible for the first time. In



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Sara Molina's *La Sabrosa Cocina Mexicana* (Editores Mexicanos Unidos, 1985) you will find a recipe for corn soup (*crema de elote*) that combines the autochthonous staple grain with milk and butter. Only an Aztec purist could possibly reject this dish or the thousands of other "Mexican" dishes, from beef-stuffed tamales to citrus-macerated seviche, that could not have been prepared in Mexico before the conquest.

I point this up not to diminish the originality of Mexican food but to explain it, and to seize on the special opportunity that Mexican food offers us, to see in detail what the historical record from other cultures has rarely preserved, the evolution of a national cuisine.

France and Spain and England all produced cookbooks by the late Middle Ages that show how people (mostly aristocrats) ate in those days. And much can be deduced by comparing these recipes with recipes in subsequent books. Indeed, much of what we think of as food history is the result of such deductions. What we do not have in any significant amount for premodern European cuisines is the evidence for a social history of eating. From the literature of those days, we can, once again, deduce what Shakespeare's or Pope's dinners were like. Much can be learned in this way—and has been. But food historians of Europe would be in a better position to reconstruct the alimentary life of the continent before Napoleon if someone had set out at any time in any European country to report directly on food as a dynamic fact of life. But premodern Europe did not have food journalists. And the science of anthropology had not yet been born. Nor have we received informal pieces of food ethnography or food reporting that might, for example, help us situate in a specific way the rise of regional cuisines or the development of popular cooking styles.

Mexico is a shining exception to all this. We know in detail what native Mexicans ate before the Spanish conquest. We know how they ate their food. How they prepared it. How it fitted into the life of Aztec society. And we know this from native informants, as well as from reliable outsiders and reliable evidence in pre-Columbian and colonial Mexican art and in the survival of ancient foodways still abundantly practiced in Mexico today.

The Aztecs wrote about their own civilization, and some of this material has survived from before the conquest. Other documents of an ethnographic character were produced at the direction of the Spaniards soon after the conquest. The most famous, the Codex Mendoza or Mendocino, has illustrations of daily life, including culinary scenes. Cortés himself wrote letters, and Bernal Diaz del Castillo produced a full history of the conquest (*Historia verdadera de la conquista de la Nueva España*), based on eyewitness accounts. But the most important record of indigenous life in Mexico to come down to us from the sixteenth century is the *General History of the Things of New Spain* (*Historia general de las cosas de Nueva España*), written by the Franciscan friar Bernardino de Sahagún.

Sahagún's monumental work is based on Aztec testimony that he faithfully gathered and eventually translated from the Nahuatl language of his informants into Spanish. It is a big book and covers the whole panorama of Aztec life in great detail. Foodways are not slighted. From Sahagún, we know that the Aztecs' diet was based on corn and tortillas, tamales, and plenty of chiles in many varieties. In other words, Sahagún provides evidence for a continuity between Aztec food and demotic Mexican food of today.

In Book VIII, an account of aristocratic life, Sahagún devotes chapter 13 to enumerating the foods the Aztec noblemen were accustomed to:

"1. The tortillas the lords ate every day were called *totonqui tlaxcalli tlacuelpacholli,* meaning white and hot tortillas, folded tortillas, piled in a *chiquihuitl,* and covered with a white cloth.

"2. They also ate other tortillas every day that they called *ueitlaxcalli,* meaning big tortillas; these are very white and very thin and narrow and very smooth."

There are dozens and dozens of similar descriptions, set forth in this bilingual mixture, which is, among other things, symbolic of the mixed cuisine we know today as Mexican. Already, in the 1570s, just a half century after the arrival of Cortés's ships, the demotic flat corn bread of the Aztecs, the *tlaxcalli* in Nahuatl, had acquired a Spanish name, tortilla, that must have been in general enough use so that Sahagún felt no need to explain it—even though in peninsular Spain, then and now, tortilla, the diminutive of the word for cake (*torta*), refers to a cold omelet and nothing else.

Almost from the beginning of the fateful encounter between native Mexicans and Spaniards, then, it is legitimate to speak of mixture, *mestizaje.* The vocabulary seems to have come first; the rich repertory of mestizo recipes soon after, as Spanish settlement took hold on Mexican soil.

The importation of European-style foods began with Cortés. To celebrate victory in battle, Bernal Diaz tells us he held a banquet at Cocoyan with "much wine from Castilla" and pork from Cuba.

In 1538, the first viceroy of Mexico, Antonio de Mendoza, and Cortés held banquets to celebrate a peace treaty between Spain and France. Bernal Diaz writes magniloquently of the Mendoza feast:

Although I'm not going to write down everything, I will say what I remember, because I was one of those who dined at those great celebrations. First, there were some salads made in various ways, and afterwards, kids and hams roasted in the Genoese style; besides that there were quail and pigeon pies, and then wattled cocks and stuffed hens; then blancmange; after that a stew [*pepitoria*]; then a royal cake [*torta real*]; then local fowl and partridges and quail *en escabeche;* moreover they replaced the tablecloths twice and left clean ones with napkins; then they brought pasties [*empanadas*] filled with every kind of bird and game; these they did not eat, nor many other things that had been served to them; then came fish *empanadas;* neither did they eat any of them; then they brought in roast mutton, and beef and pork, and turnips and cabbage and chickpeas; of which they also ate nothing; and in the midst of these dishes, they put down fruits of different flavors and then they brought local fowl boiled whole, with beaks and feet covered with silver; after that whole ducklings and goslings with gilded beaks, and then hogs' heads and whole stags and calves, of great size, and along with these came large bands with singers at either end of each table and brass players and other kinds of instruments, harps, viols, flutes, treble and alto shawms [*chirimias y dulzainas*], especially when the stewards passed cups to the ladies who were dining there, many more than had

Pato con Salsa de Capulin (Duck with Sour Cherry Sauce)

(Adapted from a recipe of Arnulfo Luengas in *El Universo de la Cocina Mexicana, Recetario,* Banamex, 1988)

- 4 3½ pound ducks
- 1 bottle ruby port
- 4 pounds capulin or other sour cherries, unpitted
- 4 cups chicken stock
- ½ pound sugar
- Cornstarch

1. Preheat oven to 425 degrees.
2. Roast duck for about 15 minutes, until browned. Remove fat and add the port, half the capulins, and the chicken stock to the roasting pan. Bring to a boil on top of the stove, return to oven, and lower heat to 350 degrees. Continue roasting for 50 minutes or until duck is done.
3. Push the cooked capulins through a strainer, leaving the stones to discard. Caramelize the sugar. Now combine the strained fruit pulp, the sugar, and

attended Cortés's dinner, and many gilt goblets, some with hydromel, others with wine and others with water, others with chocolate and with claret; and afterwards they served other, more important ladies even bigger *empanadas,* and in some of them were pairs of live rabbits, and others were full of live quail and pigeons and other little birds; and they served them all at the same time; and when the waiters took them away, the rabbits ran away across the tables and the quail and birds flew off. And I still haven't said anything about olives and radishes and cheese and cardoons. And local fruit. But what more is there to say except that the table was full for that course. At the same time, there were clowns and jesters who said many funny things in praise of Cortés and the viceroy. And I still haven't talked about the fountains of white wine, made by Indians, and red wine, too, that they put in front of us. . . . Then I almost forgot to mention the heifers, roasted whole and stuffed with chickens and fowl and quail and pigeons and ham . . . And all this was served with gold and silver and very luxurious big china plates.

Even if only part of this New World feast of Trimalchio, with all its exotic Old World extravagances, ever was served, it is no wonder that Sahagún was worried about preserving indigenous food traditions and terms. The greater wonder is that so much of what Mexico ate before Cortés is still available today and popularly consumed, from cactus paddles to chilies, from tadpoles to various worms and bugs.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

the duck cooking liquid and bring to a boil. Strain. Add remaining whole fruit. Heat through. To thicken, stir in a small amount of cornstarch.

4. Carve the ducks in quarters. Arrange on plates and cover with the sauce.

Yield: 8 to 10 servings

Salsa de Jumiles (Mountain chinch sauce)

(From Adela Fernandez's *La Tradicional Cocina Mexicana y sus Mejores Recetas,* Panorama Editorial, Mexico, 1989)

A handful of live mountain chinches (pentatomids, or flat true bugs)
15 Mexican green tomatoes (*tomates verdes* or, as sold in the United States, tomatillos), husked
2 cloves garlic, peeled
¼ onion, peeled and finely chopped

1. Pound everything to a paste in the *molcajete* (mortar). The green tomatoes are used in their green state, not in the fully mature yellow state.

Yield: About 1 cup sauce

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—Charles C. Mann

Photograph by
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Despite its bad weather and barre appearance, Yankich Island became favorite field locality for **Michael Propp** (left) and (right) **Vitaly Tarasov** (page 28); in addition to its sc entific interest, the island's hot spring were a perfect place to relax after a da of diving in wet suits. Both authors ar associated with the Institute of Marin Biology in Vladivostok. Tarasov specia izes in the biology of bottom-dwelling in vertebrates and headed four expedition to study the fauna of Kraternaya Bay Propp is the head of the Institute's Lab oratory of Productivity and studies ma rine ecosystems. With more than thirty years of diving experience, Propp ha pioneered the use of scuba diving for sc entific research in the Soviet Union. H also is an avid mountain climber an photographer. For further information about the biology of hydrothermal ven animals, one can read, "Symbiosis in th Deep Sea," by James Childress, Hors Felbeck, and George Somero (*Scientifi American*, May 1987).

For the past two years, **Carol A. Shively** (page 34) has been a ranger and naturalist at Yellowstone National Park; during the summer of 1988, she served as a fire information officer. Before coming to Yellowstone she did a two-year stint as a ranger in Sequoia and Kings Canyon national parks in California. A native of California, Shively spent her first eighteen summers in Montana, where generations of her family have lived, so her attraction to the Yellowstone area came naturally. She spends free moments on creative writing, classical piano, and folk music. For further reading on the Yellowstone fires, she recommends *Fire: The Story Behind a Force of Nature*, by Jack de Golia (Las Vegas: KC Publications, Inc., 1989), *Yellowstone: The Fires of Change*, by George Wuerthner (Salt Lake City: Haggis House, 1988), and "The History of Fire in the Greater Yellowstone Ecosystem," by William H. Romme and Donald G. Despain (*Western Wildlands*, Summer 1989).

When **Michael S. Quinton** (page 34) was sixteen, he got himself a job and used the money from his first paycheck to buy a 35-mm camera and a telephoto lens. He has been taking photographs ever since, for the last ten years on a full-time basis. Quinton lives in Island Park, Idaho, just twenty miles outside of Yellowstone National Park. The park, says Quinton, "has about the most diverse wildlife ecosystem in North America," so he rarely travels, concentrating instead on photographing the animals of the region. He is now finishing the photography for a book on Yellowstone wildlife, and another on the common loon is now in the process of being produced by Northland Publishing Co. A previous Northland book on the great gray owl (*Ghost of the Forest*) appeared in 1988. Quinton describes himself as "obsessive" about his photography, but he has found some free time to build a cabin for himself, his wife, Cindy, and his 2½-year-old daughter, Rebecca.

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Stephen J. Pyne (page 44), a professor of history at Arizona State University at Phoenix, spent fifteen summers (1967–81) as part of a fire crew on the Grand Canyon's North Rim. During roughly the same period, he earned an undergraduate degree in English from Stanford University and a master's and doctorate in American civilization from the University of Texas. Pyne is the author of a book on the cultural history of fire in the United States and a textbook on fire management, and has assisted in fire planning at several national parks. Currently researching the history of fire in Australia, he is a MacArthur fellow, which will free him to research an even more ambitious project—a general history of fire on earth. For a summary of last summer's events, he recommends *Summer of Fire: The Great Yellowstone Fires of 1988,* by Jim Carrier (Layton: Peregrine Smith Books, 1989), and for a provocative critique of the ideologies behind the park's resource management, *Playing God in Yellowstone,* by Alston Chase (New York: Harcourt Brace Jovanovich, Inc., 1987).

At age seven, **Michael H. Hansell** (page 52) watched some "pet" caterpillars spin their cocoons, an event that sparked his interest in animal architecture. As an undergraduate, he studied the house-building behavior of caddis fly larvae, and twelve years ago he turned his attention toward the relationship between the nest building of wasps and their social organization. Currently, Hansell is also investigating the way rooks (British cousins of the crow) construct their stick nests. Stick stealing is a common occurrence among these birds, perhaps because thievery takes less time and energy than gathering one's own sticks. In the future he hopes to look into how birds use spider and caterpillar silk in their nests. Hansell is senior lecturer in the Zoology Department of Glasgow University, Scotland, and the author of *Animal Architecture and Building Behavior* (London: Longman Group, Ltd., 1984). Two other relevant books on the subject of nest building are Karl von Frisch's *Animal Architecture* (New York: Van Nostrand Reinhold, 1983) and Nicholas E. and Elsie C. Collias's *Nest Building and Bird Behavior* (Princeton: Princeton University Press, 1984).

Kathie Atkinson (page 80) began her career as a photographer with the Australian Broadcasting Commission. For many years this meant traveling with documentary film crews to remote regions of the Australian outback, a perfect job for a frustrated naturalist. In 1979, a diving holiday on the Great Barrier Reef focused Atkinson's attention on marine invertebrates. Unable to dive regularly, she began collecting specimens from the intertidal zone of the local beaches and taking them back to her studio for filming. In 1982, she decided to leave her full-time job to become a freelance naturalist-photographer. "Photographing marine invertebrates," Atkinson says, "has involved me in more than just gathering specimens and battling with technological problems. I learn as much as possible about the biology and behavior of my subjects." Two books that she keeps at hand are Alister Hardy's *The Open Sea* (Boston: Houghton Mifflin Co., 1971) and Leon A. Zann's *Living Together in the Sea* (Neptune: TFH Publications, Inc., 1980). Atkinson shot this month's "Natural Moment" with an Olympus OM2n, using Kodachrome film 64ASA, a 50-mm macro lens, and three Olympus flashes.

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SEPTEMBER 1989

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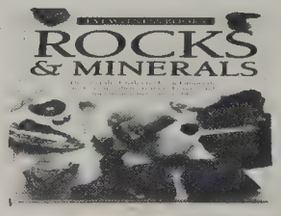

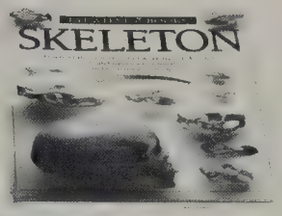

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CATS AND CLOVER

No doubt every reader will be distressed (and fascinated) to learn how many and various are the prey of the domestic cat in English villages (Peter B. Churcher and John H. Lawton, "Beware of Well-fed Felines," July 1989). But distress may be tempered by considering "how plants and animals, most remote in the scale of nature, are bound together by a web of complex relations" (Charles Darwin, *On the Origin of Species*, 1859).

Darwin goes on to illustrate the web: "Humble-bees are indispensable to the fertilization of the heartsease (*Viola tricolor*), for other bees do not visit this flower . . . humble-bees alone visit the common red clover (*Trifolium pratense*), as other bees cannot reach the nectar. . . . The number of humble-bees in any district depends in great degree on the number of field-mice which destroy their combs and nests . . . Now the number of mice is largely dependent, as everyone knows, on the number of cats. Hence . . . the presence of a feline animal in large numbers in a district might determine, through the intervention first of mice and then of bees, the frequency of certain flowers in that district!"

Perhaps a flower is not worth a mouse (or a bird), but English villagers who adopt a cat may be comforted to know that its depredations are not entirely without issue.

MICHAEL STUDDERT-KENNEDY
Great Neck, New York

Although a well-fed feline is a better hunter than a starved one, it is absurd to state that felines, well fed or otherwise, should be held responsible for the killing of wild birds and mammals. A responsible cat owner knows that allowing a cat freedom to come and go from the house will result in a hunting trip and should not allow the cat such freedom. I have never allowed my cats this freedom. My reasons include the danger of disease and parasites they can get from catching wild game. Rabies poses a threat to the family cat, even if vaccinated, and I care too much to expose my cats to such danger.

The owners of the cats in the survey are irresponsible. These cats are not household pets, but semiwild animals. We humans are responsible for our pets' actions. We can control them and some of us do.

RHONDA V. HUBBS
Baton Rouge, Louisiana

The finding that the domestic house cat is one of the major enemies of small birds comes as no surprise to any bird rehabilitator. In addition to the innumerable cat-inflicted casualties we are called upon to treat, again and again we are told, when we urge the caller to leave a fledgling with its parents, "We can't leave it. The cats have already killed all its nestmates." Thanks to the permissive attitude of even the bird-conscious public, cats enjoy the best of both worlds—classified as domestic and hence under man's protection, and also as wild, free to roam and follow their natural instincts.

CATHERINE A. HURLBUTT
Denver, Colorado

David Nadig; Photo Researchers

The article on predatory suburban cats in your July issue is one that should be taken to heart by all true animal lovers and environmentalists. A similar article could be written on pet dogs. Suburbanites have been slow to face the fact that all domestic dogs and cats, no matter how pampered, are born killers. In suburbia, it is not so much humans who drive away the native fauna, but their pets. It is a poignant and continuing tragedy that those who love animals most, and show that love by their steadfast attachments to their pets, do the most to eliminate wild animals from the vicinity of their homes. Imagine trying to exist as a small animal with vulnerable offspring in a territory where dogs and cats live to the tune of several an acre! It cannot be done; when we move onto a piece of ground with our pets, the native animals must move or die.

WILLIAM V. DICKINSON
Tucson, Arizona

TICKS VERSUS FIRE ANTS

In regard to your article about Lyme disease ("The Lyme Disease Invasion," July 1989), it's a pity that you can't import a few colonies of fire ants. They wiped the ticks out at my place. Before they moved into this area you couldn't walk through high grass without becoming covered with ticks. Now I haven't seen a tick of any kind for over five years.

CHARLES BULLARD
Belmont, Louisiana

UNNATURAL RINGS

"If Looks Could Kill" ("The Natural Moment," July 1989) features a picture of a spider with very striking eyes. Unfortunately, the white rings in the eyes, which give the picture its striking characteristic, are artifacts: reflections of the ring light used to take the photograph.

J. E. HERNANDEZ
Hampton, Virginia

OWLS AND RATTLERS

In the sidebar to "Rattler Battlers" (May 1989), Matthew Rowe says that "examples of acoustic mimicry are almost unknown in biology." Has he never heard a parrot, not to mention mockingbirds and catbirds? Right now, a Steller's jay outside my window is imitating a red-tailed hawk. My cat twitters when stalking birds, presumably to fool his prey into thinking it is just another bird rustling the grass. When threatened, gopher snakes vibrate their tails against leaves in imitation of rattlesnakes. I'm willing to bet that some predators, especially among insect eaters, imitate the mating calls of their prey.

ELLEN K. SHURTLEFF
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Trespassers Will Be Poisoned

Fungi help grasses ward off their nibbling enemies

by Keith Clay

Walt Whitman wrote, "I believe a leaf of grass is no less than the journey-work of the stars." This attitude that ordinary grasses are a pinnacle of creation may be more poetic than popular, but new scientific findings are revealing some surprising complexities about these familiar plants. Often the tranquil blades that inhabit our lawns or wave on prairielands are filled with fungi that exude toxic chemicals. As a result, animals that eat these grasses are sickened or killed, giving the plants a victory in their continual struggle for existence.

My research has focused on tall fescue grass (*Festuca arundinacea*), a species that provides one of the best-understood examples of a partnership between a grass and a fungus. Tall fescue is a widespread perennial, covering more than 35 million acres of lawns, fields, and pastures in the United States, especially in the east. In many ways it is an ideal grass; it is vigorous and persistent under many conditions, and plants free of fungus provide good forage for livestock.

Tall fescue plants that turned out to contain fungus first attracted attention in the 1930s, on the farm of W. M. Suiter in Menifee County, Kentucky. A scientist from the University of Kentucky visiting the farm was impressed with a luxuriant stand of fescue growing on a hill. Seeds were collected and brought back to the university for field testing. The grass was very successful in these trials, and as a result, a commercial variety called Kentucky-31 was developed and widely distributed, becoming the predominant variety of tall fescue. These early researchers did not realize, however, that they were distributing a time bomb of sorts.

Within ten or fifteen years, people became aware that cattle grazing on this grass often exhibited alarming physical and behavioral disorders with no apparent cause. In summer months they would become lethargic and cease grazing, preferring to stand in the shade or in water. Animals panting and drooling excessively were a common sight. Symptoms even more severe soon followed if the animals were not moved to other forage. Their hair became rough and matted, and their body temperature increased to fever levels. Beef cattle were slow to gain weight, and milk production plummeted. Cows had difficulty conceiving, and those that did had high rates of spontaneous abortion. The most dramatic manifestation was gangrene: sick cattle lost their tails, ears, and feet to this horrible affliction. Death sometimes followed, although the animals were usually slaughtered first for their salvage value. Ironically, Kentucky-31, pushed as an improvement for farmers, was often far more of a detriment.

The cause of these problems remained undetermined until the mid-1970s, when scientists at the University of Georgia made the unexpected discovery that fescue pastures where cattle suffered the most severe symptoms were highly infected with an unknown fungus that lived inside the aboveground parts of the grass. The fungus appeared as a network of hyphae—the highly branched, tubular

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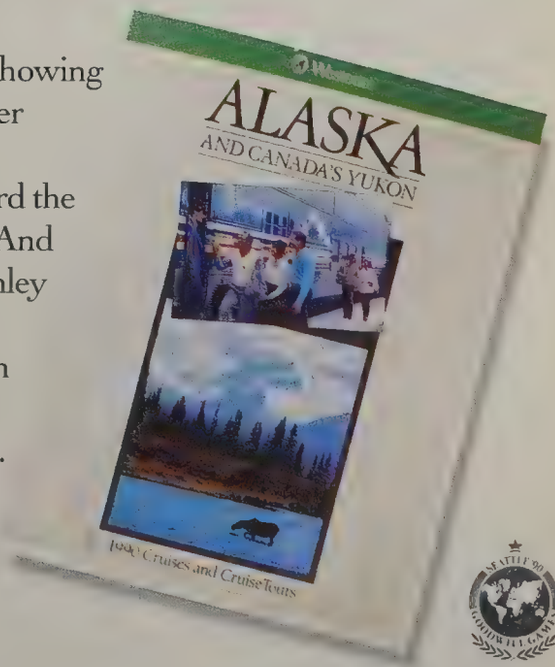

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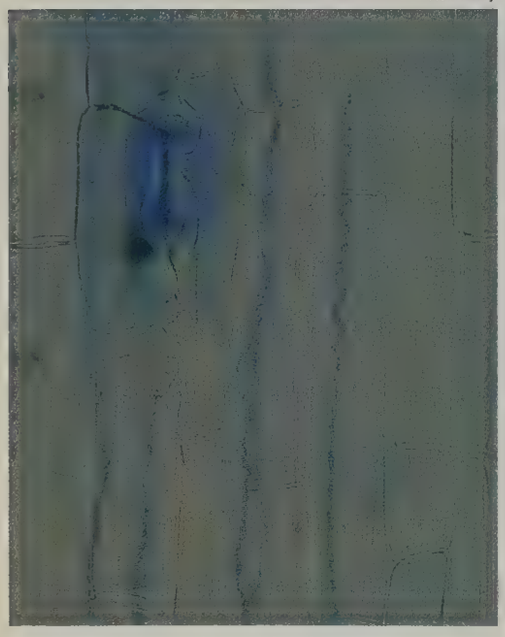
structures that are the basic growth form of most fungi—running throughout the interior of leaves, stems, and seeds. Nearby fescue pastures where cattle remained healthy had little or no infection.

Scientists eventually were able to demonstrate that the problems suffered by cattle, horses, and sheep grazing tall fescue resulted from this fungus, *Acremonium coenophialum.* Hundreds of other grasses are now known to be infected by similar fungi. (For biologists, by the way, the term *infected* does not imply a negative effect on the plant.) Thus, the relationship between tall fescue grass and its fungus was just the most disturbing example of a common—and ancient—phenomenon.

Keith Clay



Harmless to its host, the fungus Acremonium coenophialum *lives between the cells of tall fescue grass.*

Intimate associations between two different species, known as symbioses, have arisen between fungi and grasses more than once through natural selection, usually without any connection to human pastoralism and agriculture. Such relationships evolve because they enhance the reproductive success of one or both partners. Symbioses range from the parasitic, in which one partner benefits at the expense of the other, to the mutualistic, in which both partners benefit from the interaction. The relationship between tall fescue and its fungus is mutualistic.

The fungus benefits because it gains all its nutritional needs from its host plant, outside of which it cannot live in nature; it also is disseminated within the grass seeds and so is spread widely. The fungus is a member of the class Ascomycetes, which also includes more familiar fungi such as yeasts, morels, and the agent that causes Dutch elm disease. It is called an endophytic fungus, or endophyte (*endo* meaning "within," *phyte* meaning "plant"), because it lives entirely within a plant. The presence of one organism living inside another is not unusual. The billions of bacteria that teem within the human digestive tract constitute a prime example of this life style. However, the association between tall fescue and its endophyte differs in that each grass plant is infected by only one individual fungus. This one-to-one arrangement provides an especially clear-cut biological basis for the action of natural selection.

Inside the grass plant, the fungal hyphae grow between host cells without penetrating them. This is different from what happens with most parasitic fungi, which produce knoblike projections, known as haustoria, that penetrate host cells and drain them of their nutrients. The fescue endophyte is able to satisfy all its nutritional needs with materials exuded into the spaces between plant cells. As its host grows by producing new shoots, the endophyte spreads as well, so that all parts of the grass plant remain involved.

The most unusual feature of the endophyte's life cycle takes place when the tall fescue plant begins to flower. The endophyte grows within the flowering stem and into the ovaries (but not into the pollen) of the grass. In mature seeds the endophyte can be found, in a dormant state, surrounding the dormant embryo. Such seeds, probably because they are the products of more vigorous parents, germinate faster and produce more vigorous seedlings than those lacking the fungus.

As the seedling begins to grow, the endophyte grows out of the old seed and into the young plant. There is no known way for a germinating plant that has the fungus to become free of it by natural means. The endophyte is thus passed on from the mother plant rather than being "caught" from another plant. Unlike most fungi, the endophyte does not spread by means of spores, for it lacks the ability to reproduce sexually.

While the endophyte therefore depends mightily on its host, the tall fescue plant also benefits from the relationship because infected plants are much less likely to be eaten than uninfected ones. Infected plants are often toxic to grazing animals because chemicals called alkaloids are produced by the fungus. There are thousands of types of alkaloids, and most are produced by plants. Examples include caffeine, nicotine, quinine, cocaine, and morphine. All are bitter, nitrogen-rich compounds that have physiological effects on humans and other animals.

Most scientists agree that in nature the primary role of many alkaloids is protection against animals. Thus, compounds such as nicotine and cocaine represent poisons produced by plants to ward off feeding insects and other animals. Such protection is perhaps even more vital for fungi and other microorganisms, which, unlike plants, have no complex anatomical structures for defense, such as spines. Instead, fungi and bacteria are chemists *extraordinaire.* Chemicals produced by microorganisms in decaying fruit, moldy seeds, and rotting meat not only give them protection but also effectively prevent their food resource from being eaten by anything else. Endophytes exhibit the same basic strategy, but in their case, the resource that they are monopolizing is a living grass.

Compared with other plants, grasses are remarkably free of chemical toxins that might protect them against grazing animals. Tall fescue in effect uses the fungal endophyte for its own benefit, since the endophyte is capable of producing poisons far more potent than anything the grass itself can produce.

Large grazing mammals are quite adept at avoiding endophyte-infected grasses when given the opportunity. Most likely they learn through experience that plants tasting of alkaloids make them feel sick. Field experiments have shown that where plots of infected tall fescue are intermixed with uninfected plots, free-ranging cattle can discriminate between the two and strongly prefer the uninfected plants. But in many situations, animals are confined to a fenced pasture and have less choice. Animals then are faced with the dilemma of eating toxic tall fescue or starving. In such cases, cattle reduce their forage intake, and the infected pastures suffer less damage than comparable uninfected pastures.

Livestock avoid other species of endophyte-infected grasses. For example, after observing horses feeding on a grass called sleepy grass, which is infected by endophytes, a range scientist wrote, "All agree on the species, on its effects, and to the fact that after one good dose of sleepy grass, horses will never touch it again." Similarly, a scientist made the following statement about a related grass from India: "Its prevalence in the Kulu Valley is said to be due to the fact that cattle become too knowing to eat it."

While gangrenous cattle are more dramatic than stricken aphids or other inconspicuous insects, the effect of alkaloids on insects is probably of greater ecological significance than their effect on livestock. Because of its tough leaves, tall fescue is

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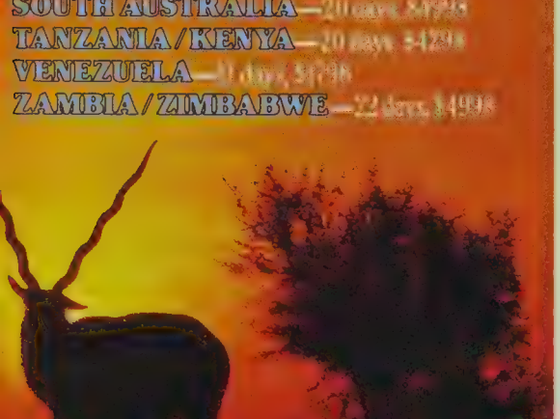

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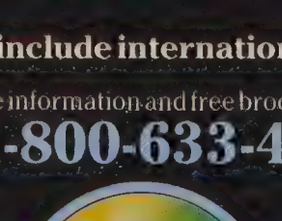

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less vulnerable to insects than many other grasses, but it nevertheless can be severely damaged by them. Scientists at Rutgers University found that endophyte-infected fescues in lawns and other mown areas were damaged much less by sod webworms, a major insect pest of mown grasses, than were uninfected plants. And at the University of Kentucky, scientists determined that aphids exhibited a very strong preference for uninfected plants.

In a similar vein, workers at the University of Arkansas found fewer nematodes (microscopic worms) living and feeding on plant roots in soil where infected tall fescue was grown. Possibly as a result of avoiding nematode damage and thus retaining a healthier root system, endophyte-infected tall fescue plants throughout the Southeast survived the severe drought during the summer of 1988 very well, while uninfected plants suffered much greater mortality.

In my own research, I have investigated the effect of the endophyte on the fall armyworm, whose adult form is a drab moth. The larval caterpillars prefer corn and rice but feed on a variety of other grasses, including tall fescue, which they can damage extensively. In experiments conducted in the laboratory, in which both infected and uninfected leaves were provided to the insects, twice as many caterpillars preferred uninfected plants. And in greenhouse experiments where live plants grew intermixed, fall armyworms ate the uninfected plants to the ground before they even began to feed on infected plants.

Since the endophyte also occurs in the seeds of tall fescue, I was interested in whether seed-feeding animals were deterred by the endophyte. Although a healthy plant can sustain considerable damage to its leaves (witness the mowing of lawns), damage to the seed results in death of the embryo. In an experiment with flour beetles, the common pests of stored grain products, all beetles died when fed ground, infected seeds, but they thrived on uninfected ones. Observations on juncos, birds that forage for plant seeds on the ground, revealed that when an equal abundance of infected and uninfected tall fescue seeds were provided, over 80 percent of the seeds the birds chose to eat were uninfected.

Some types of alkaloids produced by the tall fescue endophyte have been known for hundreds of years, but from another, closely related fungus called ergot. The parasitic ergot fungus (*Claviceps purpurea*) infects ovaries of many wild and cultivated grasses, appearing as conspicuous outgrowths from the flowers. Accidental ingestion of ergot in contaminated grain, with the various alkaloids it produces, results in a toxic reaction historically known as *ignis sacer* (holy fire) or Saint Anthony's fire. Medieval Europeans who ate bread tainted with ergot suffered a variety of terrible symptoms, including skin lesions, mental delusions, hallucinations, and intense tingling or burning sensations in the fingers and toes—hence the "fire"—which could presage gangrene. Affected people were thought to be mad or possessed and were sometimes killed by fearful neighbors. Some have suggested that the Salem witch trials resulted from accidental ergot poisoning and the strange behavior of so-called witches.

The primary physiological effect of ergot alkaloids is to cause small blood vessels to constrict. While this can be deleterious, for example, when the cessation of blood flow to extremities causes gangrene, there are certain circumstances where this effect is beneficial. For hundreds of years European doctors and midwives have ad-

Eckart Pott

Parasitic ergot fungus on ears of rye

ministered the ergot fungus during and immediately following the labor of childbirth. One particular ergot alkaloid, ergonovine, has been singled out for this purpose and is one of the drugs used in the United States today to induce uterine contractions and to reduce bleeding following delivery. Another ergot alkaloid, ergotamine, acts to shrink blood vessels in the brain and is used to treat migraines.

Constriction of blood vessels in the brain can lead to convulsions and death, but consumption of ergot alkaloids would have to be unusually high to produce such consequences. More obvious is how some of them interfere with the chemicals that regulate the neural activity in the brain. One alkaloid, lysergic acid amide, is a powerful hallucinogen; the effects of its

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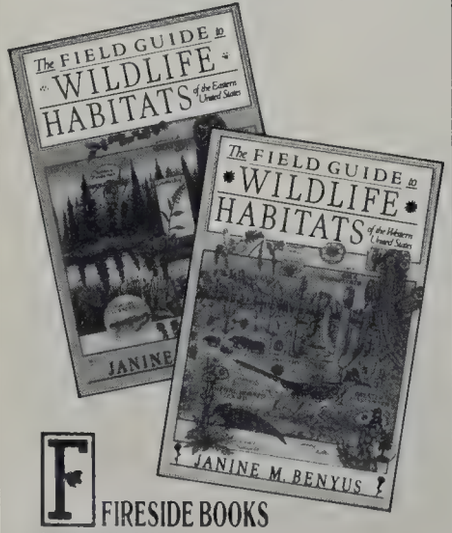
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Ergot sprouts its fruiting bodies

synthetic derivative, lysergic acid diethylamide (LSD), are widely known.

Such uses for ergot exist among cultures around the world. For instance, native people in the Amazon region use an endophyte-infected sedge for obstetric purposes and in magical/religious ceremonies, the effects of which suggest the presence of ergot alkaloids.

Cattle eating ergot-infected grasses display poisoning symptoms similar to those of cattle eating tall fescue. In fact, when early researchers looked for the cause of the poisoning in fescue pastures, they at first suspected that ergot was the culprit, but thorough searches of the pastures failed to reveal any. After discovering the endophyte growing inside toxic tall fescue, however, scientists were able to grow it in pure cultures in the laboratory and show that it produced ergot alkaloids. Added to animal diets, these pure ergot alkaloids induced all the symptoms suffered by animals grazing infected tall fescue.

Another common grass of some notoriety in human affairs is darnel, an annual ryegrass often poisonous to livestock. It grows as a weed in wheat fields in Europe, and its seeds are sometimes harvested along with the grain. Accidental consumption of infected darnel can cause severe illness and blindness. In *Henry VI,* Part 1, act 3, Shakespeare wrote:

> want ye corn for bread?
> I think the Duke of Burgundy will fast
> Before he'll buy again at such a rate
> 'Twas full of darnel: Do you like the taste?

Nearly one hundred years ago, the German biologist A. Vogl discovered that darnel seed often contained an endophyte. It is similar to the one in tall fescue, and again, fungal alkaloids are present, although they differ from ergot alkaloids.

The mutualistic relationship between the endophyte *Acremonium coenophialum* and tall fescue is unlikely to have appeared just as we see it today. Instead, the endophyte probably descended from an ancestral fungus that was more detrimental to its host. *Epichloe typhina,* a fungus that causes the disease called choke in grasses, is intermediate between the tall fescue endophyte and ergot. Like the endophyte, it grows inside the stems and leaves of grasses. But, like ergot, the choke fungus also produces a large reproductive structure that envelops and aborts the developing flowers of its host. This structure produces spores that can infect new plants.

Occasionally, host plants flower normally and the choke fungus grows into the ovaries and seeds exactly as does the endophyte of tall fescue. Probably, the endophyte of tall fescue arose from a choke fungus that completely lost its capacity for reproduction. The loss of the spore-producing structure meant that infected plants were able to produce seeds, eliminating the major detrimental effect of infection. This evolutionary change may have occurred many times, with respect to different species. Both the choke fungus and endophytes similar to the one in tall fescue infect hundreds of grasses.

The relationship between tall fescue and its endophyte might never have been discovered if it were not for the commercial development of infected tall fescue as a forage grass and the widespread problems with livestock that resulted. The economic consequences for agriculture remain staggering. Annual losses in beef to the fungus in the southeastern United States alone may total as much as $500 million annually. Unfortunately for the farmer, infected tall fescue is like the Hydra of Greek mythology. Attempts to eradicate it with herbicides rarely are completely successful. If a good stand of uninfected fescue is established from uninfected seed, it is not as vigorous as infected plants, and over time, the few infected plants that survive, and their progeny, soon dominate the pasture.

Taken from nature and put into an agricultural context, infected tall fescue poses a serious economic problem. But in nature, it represents a harmonious symbiosis that tends to displace uninfected plants. Humans can still exploit this association by utilizing infected grasses in lawns, roadsides, athletic fields, and other places where livestock do not graze. In these situations, resistance to insect pests and greater vigor under environmental stresses are welcome characteristics.

Keith Clay is assistant professor of biology at Indiana University, Bloomington.

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Through a Lens, Darkly

Do species change by random molecular shifts or natural selection?

by Stephen Jay Gould

Double-entendre can be delicious. Who does not delight in learning that Earnest, in Oscar Wilde's play, is a good chap, not a worthy attitude. And who has ever begrudged that tragic figure his little joke. But double meanings also have their dangers—particularly when two communities use the same term in different ways, and annoying confusion, rather than pleasant amusement or enlightenment, results.

Differences in scientific and vernacular definitions of the same word provide many examples of this frustrating phenomenon. "Significance" in statistics, for example, bears little relation to the ordinary meaning of something that matters deeply. Mouse tails may be "significantly" longer in Mississippi than in Michigan—meaning only that average lengths are not the same at some level of confidence—but the difference may be so small that no one would argue for significance in the ordinary sense. But the most serious of all misunderstandings between technical and vernacular haunts the concepts of probability, and particularly the words *random* and *chance*.

In ordinary English, a random event is one without order, predictability, or pattern. The word connotes disaggregation, falling apart, formless anarchy, and fear. Yet, ironically, the scientific sense of *random* conveys a precisely opposite set of associations. A phenomenon governed by chance yields maximal simplicity, order, and predictability—at least in the long run. Suppose that we are interested in resolving the forces behind a large-scale pattern of historical change. Randomness becomes our best hope for a maximally simple and tractable model. If we flip a penny or throw a pair of dice, once a second for days on end, we achieve a rigidly predictable distribution of outcomes. We can predict the margins of departure from 50–50 in the coins, or the percentage of sevens for our dice, based on the total number of throws. When the number of tosses becomes quite large, we can give precise estimates and ranges of error for the frequencies and lengths of runs—heads or sevens in a row—all based on the simplest of mathematical formulas from the theory of probability. (Of course, we cannot predict the outcome of any particular trial or know when a run will occur, as any casual gambler should—but so few do—know.)

Thus, if you wish to understand patterns of long historical sequences, pray for randomness. Ironically, nothing works so powerfully against resolution as conventional forms of determinism. If each event in a sequence has a definite cause, then, in a world of such complexity, we are lost. If *A* happened because the pond thawed on a particular day, leading to *B* because Billy the Seal swam by and gobbled up all those fishes, followed by *C* when Sue the Polar Bear sauntered through—not to mention ice age fluctuations, impacting asteroids, and drifting continents of the truly long run—then how can we hope to predict and resolve the outcome?

The beauty (and simplicity) of randomness lies in the absence of these maximally confusing properties. Coin flipping permits no distinctive personality to any time or moment; each toss can be treated in exactly the same way, whenever it occurs. We can date geological time with precision by radioactive decay because each atom has an equal probability of decaying in each instant. If causal individuality intervened—if 10:00 A.M. on Sunday differed from 5:00 P.M. on Wednesday, or if Joe the uranium atom resisted decay, by dint of causal effort, more than his brother Tom—then randomness would fail and the method would not work.

One of the best illustrations for this vitally important, but counterintuitive, principle of maximal long-term order in randomness comes from my own field of evolutionary biology—and from a debate that has greatly contributed to making professional life more interesting during the past twenty years. Traditional Darwinism includes an important role for randomness—but only as a source of variation, or raw material, for evolutionary change, not as an agent for the direction of change itself. For Darwin, the predominant source of evolutionary change resides in the deterministic force of natural selection. Selection works for cause and adapts organisms to changing local environments. Random variation supplies the indispensable "fuel" for natural selection but does not set the rate, timing, or pattern of change. Darwinism is a two-part theory of randomness for raw material and conventional causality for change—*Chance and Necessity*, as so well epitomized by Jacques Monod in the title of his famous book about the nature of Darwinism.

In the domain of organisms and their good designs, we have little reason to doubt the strong, probably dominant influence of deterministic forces like natural selection. The intricate, well-functioning forms of organisms—the wing of a bird or the mimicry of a dead twig by an insect—are too complex to arise as long sequences of sheer good fortune under the simplest random models. But this stricture of complexity need not apply to the nucleotide-by-nucleotide substitutions that build the smallest increments of evolutionary change at the molecular level. In this domain of basic changes in DNA, a "neutralist" theory, based on simple random models, has been challenging conventional Darwinism with marked success during the past twenty years.

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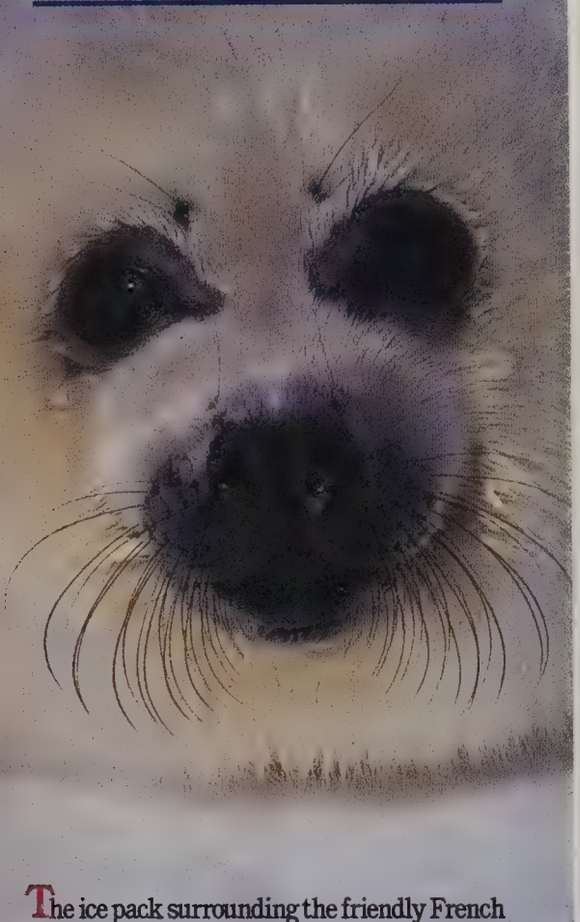

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When the great Japanese geneticist Motoo Kimura formulated the first version of neutral theory in 1968 ("Evolutionary Rate at the Molecular Level," *Nature*, volume 217, pages 624–26), he was impressed by two discoveries that seemed difficult to interpret under the conventional view that natural selection overwhelms all other causes of evolutionary change. First, at the molecular level of substitutions in amino acids, measured rates indicated a constancy of change across molecules and organisms—the so-called molecular clock of evolution. Such a result makes no sense in Darwin's world, where molecules subject to strong selection should evolve faster than others, and where organisms exposed to different changes and challenges from the environment should vary their evolutionary rates accordingly. At most, one might claim that these deterministic differences in rate might tend to "even out" over very long stretches of geological time, yielding roughly regular rates of change. But a molecular clock surely gains an easier interpretation from random models. If deterministic selection does not regulate most molecular changes; if, on the contrary, most molecular variations are neutral, and therefore rise and fall in frequency by the luck of the draw, then mutation rate and population size will govern the tempo of change. If most populations are large, and if mutation rates are roughly the same for most genes, then simple random models predict a molecular clock.

Second, Kimura noted the recent discovery of surprisingly high levels of variation maintained by many genes among members of populations. Too much variation poses a problem for conventional Darwinism because a cost can be associated with the replacement of an ancestral gene by a new and more advantageous state of the same gene—namely, the differential death, by natural selection, of the now disfavored parental forms. This cost poses no problem if only a few old genes are being pushed out of a population at any time. But if hundreds of genes are being eliminated, then any organism must bear many of the disfavored states and should be ripe for death. Thus, selection should not be able to replace many genes at once. But the data on copious variability seemed to indicate a caldron of evolutionary activity at far too many genetic sites—too many, that is, if selection governs the changes in each varying gene. Kimura, however, recognized a simple and elegant way out of this paradox. If most of the varying forms of a gene are neutral with respect to selection, then they are drifting in frequency by the luck of the draw. Invisible to natural selection because they make no difference to the organism, these variations impose no cost in replacement.

In twenty years of copious writing Kimura has always carefully emphasized that his neutral theory does not disprove Darwinism or deny the power of natural selection to shape the adaptations of organisms. He writes, for example, at the beginning of his epochal book *The Neutral Theory of Molecular Evolution* (1983, Cambridge University Press):

> The neutral theory is not antagonistic to the cherished view that evolution of form and function is guided by Darwinian selection but it brings out another facet of the evolutionary process by emphasizing the much greater role of mutation pressure and random drift at the molecular level.

The issue, as so often in natural history (and as I emphasize so frequently in these essays), centers upon the relative importance of the two processes. Kimura has never denied adaptation and natural selection, but he has tended to view these processes as quantitatively insignificant to the total picture—a superficial and minor ripple upon the ocean of neutral molecular change, imposed every now and again when selection casts a stone upon the waters of evolution. Darwinians, on the other hand, at least before Kimura and his colleagues advanced their potent challenge and reeled in the supporting evidence, tended to argue that neutral change occupied a tiny and insignificant corner of evolution—an odd process occasionally operating in small populations at the brink of extinction anyway.

This argument about relative frequency has raged for twenty years and has been, at least in the judgment of this bystander with no particular stake in the issue, basically a draw. More influence has been measured for selection than Kimura's original words had anticipated; Darwin's process is no mere pockmark on a sea of steady tranquility. But neutral change has been established at a comfortably high relative frequency. The molecular clock is neither as consistent nor as regular as Kimura once hoped, but even an imperfect molecular timepiece makes little sense in Darwin's world. The ticking seems best interpreted as a pervasive and underlying neutralism, the considerable perturbations as a substantial input from natural selection (and other causes).

Nonetheless, if forced to award the laurels in a struggle with no clear winners, I would give the nod to Kimura. After all, when innovation fights orthodoxy to a draw, then novelty has seized a good chunk of space from convention. But

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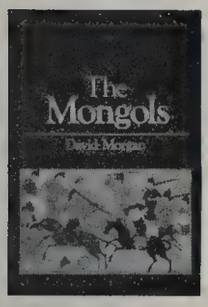

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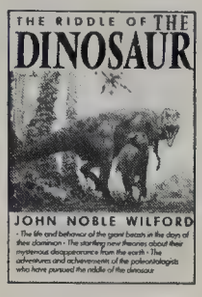

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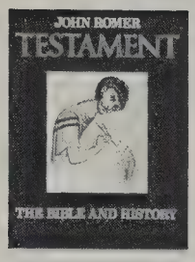

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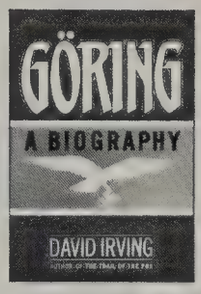

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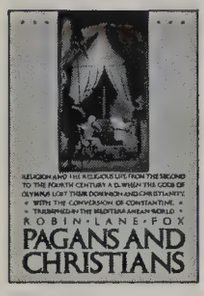

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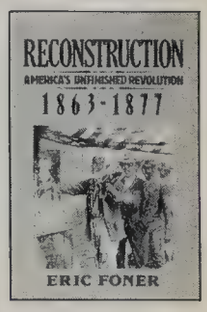

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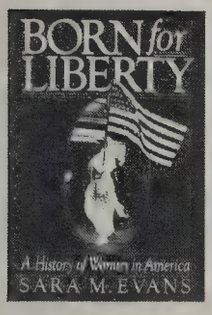

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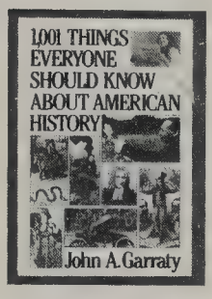

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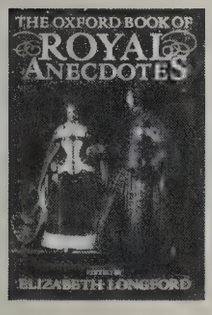

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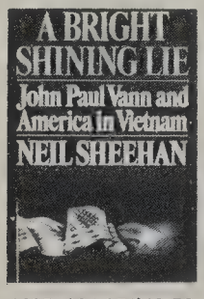

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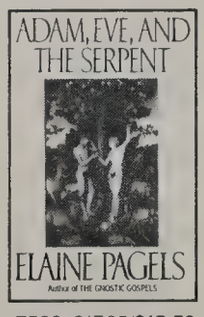

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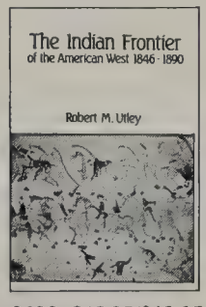

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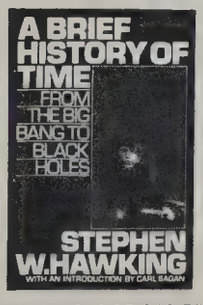

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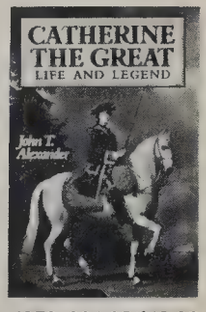

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bow to Kimura for another and more important reason than the empirical adequacy of neutralism at high relative frequency, for his theory so beautifully illustrates the theme that served as an introduction to this essay—the virtue of randomness in the technical as opposed to the vernacular sense.

Kimura's neutralist theory has the great advantage of simplicity in mathematical expression and specification of outcome. Deterministic natural selection yields no firm predictions for the histories of lineages—for you would have to know the exact and particular sequences of biotic and environmental changes, and the sizes and prior genetic states of populations, in order to forecast an outcome. This knowledge is not attainable in a world of imperfect historical information. Even if obtainable, such data would only provide a prediction for a particular lineage, not a general theory. But neutralism, as a random model treating all items and times in the same manner, yields a set of simple, general equations serving as precise predictions for the results of evolutionary change. These equations give us, for the first time, a base level criterion for assessing any kind of genetic change. If neutralism holds, then actual outcomes will fit the equations. If selection predominates, then results will depart from predictions—but in a way that permits identification of Darwinian control. Thus, Kimura's equations have been as useful for selectionists as for neutralists themselves; the formulas provide a criterion for everyone, and debate can center upon whether or not the equations fit actual outcomes. Kimura has often emphasized this point about his equations, and about random models in general. He wrote, for example, in 1982:

> The neutral theory is accompanied by a well-developed mathematical theory based on the stochastic theory of population genetics. The latter enables us to treat evolution and variation quantitatively, and therefore to check the theory by observations and experiments.

The most important and useful of these predictions involves a paradox under older Darwinian views. If selection controls evolutionary rate, one might think that the fastest tempos of alteration would be associated with the strongest selective pressures for change. Speed of change should vary directly with intensity of selection. Neutral theory predicts precisely the opposite—for an obvious reason once you start thinking about it. The most rapid change should be associated with unconstrained randomness—following the old thermodynamic imperative that things will invariably go to hell unless you struggle actively to maintain them as they are. After all, stability is far more common than change at any moment in the history of life. The ordinary mode of natural selection must preserve working combinations against a constant input of deleterious mutations. In other words, natural selection, in our technical parlance, must usually be "purifying" or "stabilizing." Positive selection for change must be a much rarer event than watchdog selection for tossing out new variants and preserving what works.

Now, if mutations are neutral, then the watchdog sees nothing and evolutionary change can proceed at its maximal tempo—the neutral rate of substitution. But if a molecule is being preserved by selection, then the watchdog slows down evolutionary change. This originally counterintuitive proposal may be regarded as the key statement of neutral theory. Kimura emphasizes the point with italics in most of his general papers, writing for example (in 1982): "*Those molecular changes that are less likely to be subjected to natural selection occur more rapidly in evolution.*"

Both the greatest success, and the greatest modification, of Kimura's original theory have arisen by applying this principle that selection slows the maximal rate of neutral molecular change. For modifications, thousands of empirical studies have now shown that watchdog selection, measured by diminished tempo of change relative to predictions of randomness, operates at a far higher relative frequency than the original version of neutralist theory had anticipated. For success, the firm establishment of the principle itself must rank as the greatest triumph of neutralism—for the tie of maximal rate to randomness (rather than to the opposite expectation of intense selection) does show that neutralism exerts a kind of base level control over evolution as a whole.

The most impressive evidence for neutralism as a maximal rate has been provided by kinds of DNA that make nothing of potential selective value (or detriment) to an organism. In all these cases, measured tempos are maximal, thus affirming the major prediction of neutralism.

1. *Synonymous substitutions.* The genetic code is redundant in the third position. A sequence of three nucleotides in DNA codes for an amino acid. Change in either of the first two nucleotides alters the amino acid produced, but most changes in the third nucleotide—so-called synonymous substitutions—do not alter the resulting amino acid. Since natural selection works on features of organisms, in this case proteins built by DNA and no directly on the DNA itself, synonymou substitutions should be invisible to selec tion, and therefore neutral. Rates c change at the third position are usuall five or more times as rapid as changes the functional first and second positions– a striking confirmation of neutralism.

2. *Introns.* Genes come in pieces, wit functional regions (called exons) inte rupted by DNA sequences (calle introns) that are snipped out and not tran lated into proteins. Introns change at much higher evolutionary rate than exon

3. *Pseudogenes.* Certain kinds of muta tions can extinguish the function of gene—for example, by preventing it eventual translation into protein. These s called pseudogenes begin with nearly th same DNA sequence as the functiona version of the gene in closely related spe cies. Yet, being entirely free from func tion, these pseudogenes should exert n resistance against the maximal accumula tion of changes by random drift. Pseud genes become a kind of ultimate test fo the proposition that absence of selectio promotes maximal change at the neutra rate—and the test has, so far, been passe with distinction. In pseudogenes, rates c change are equal, and maximal, at a three positions, not only at the third site, a in functional genes.

I was inspired to write about neutra theory by a fascinating example just pub lished on the value of this framework i assessing the causes of evolutionary rate The example neither supports nor denie neutralism but forms a case in the middl enlightened by the more important prin ciple that random models provide simpl and explicit criteria for judgment.

While supposedly more intelliger mammals are screwing up royally abov ground, Near Eastern mole rats of th species *Spalax ehrenbergi* are prosperin underneath. Subterranean mammals usu ally evolve reduced or weakened eyes, bu *Spalax* has reached an extreme state c true blindness. Rudimentary eyes are sti generated in embryology, but they ar covered by thick skins and hair. Whe exposed to powerful flashes of ligh *Spalax* shows no neurological response a all, as measured by electrodes implante in the brain. The animal is completel blind.

What then shall we make of the invi ible and rudimentary eye? Is this burie eye now completely without function, true vestige on a path of further reductio to final disappearance? Or does the ey perform some other service not related t vision? Or perhaps the eye has no direc use, but must still be generated as a pr

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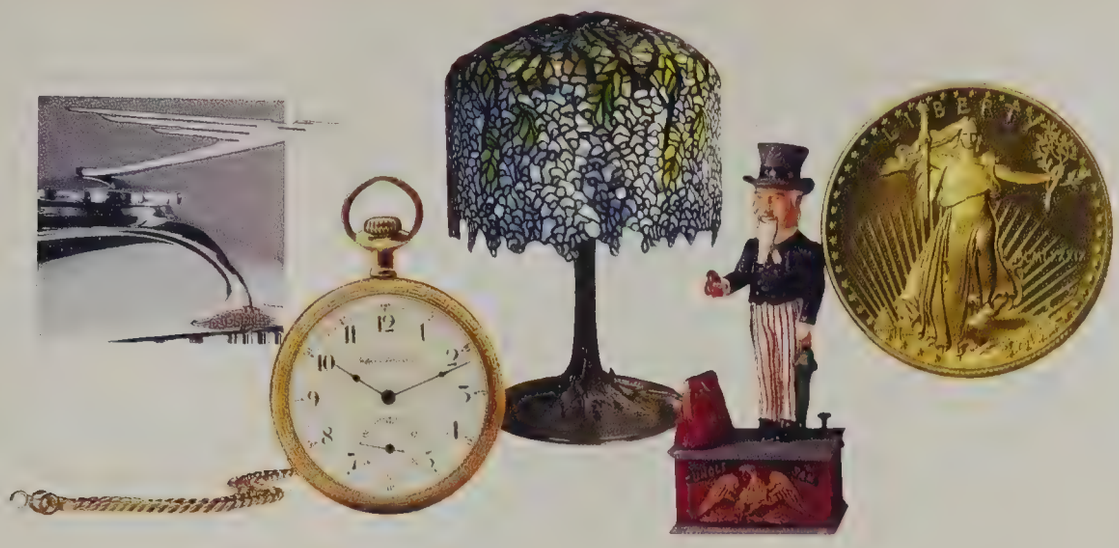

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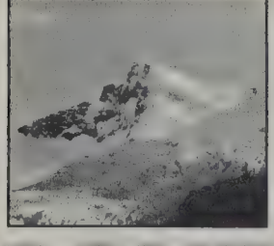

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requisite in an embryological pathway leading to other functional features. How can we decide among these and other alternatives? The random models of neutral theory provide our most powerful method. If the rudimentary eye is a true vestige, then its proteins should be changing at the maximal neutral rate. If selection has not been relaxed, and the eye still functions in full force (though not for vision), then rates of change should be comparable to those for other rodents with conventional eyes. If selection has been relaxed due to blindness, but the eye still functions in some less constrained way, then an intermediate rate of change might be observed.

The eye of *S. ehrenbergi* still builds a lens (though its shape is irregular and could not focus an image), and the lens includes a protein, called αA-crystallin. The gene for this protein has recently been sequenced and compared with the corresponding gene in nine other rodents with normal vision (W. Hendriks, J. Leunissen, E. Nevo, H. Bloemendal, and W. W. de Jong, 1987, "The lens protein αA-crystallin of the blind mole rat, *Spalax ehrenbergi*: evolutionary change and functional constraints," *Proceedings of the National Academy of Sciences*, volume 84, pages 5320–24).

Hendriks and colleagues obtained the most interesting of possible results from their study. The αA-crystallin gene is changing much faster in blind *Spalax* than in other rodents with vision, as relaxation of selection due to loss of primary function would suggest. The protein coded by the *Spalax* gene, for example, has undergone nine amino acid replacements (of 173 possible changes), compared with the ancestral state for its group (the murine rodents, including rats, mice, and hamsters). All other murines in the study (rat, mouse, hamster, and gerbil) have identical sequences with no change in amino acids from the ancestral state. The average tempo of change in αA-crystallin among vertebrates as a whole has been measured at about 3 amino acid replacements per 100 positions per 100 million years. *Spalax* is changing more than four times as fast, at about 13 percent per 100 million years. (Nine changes in 173 positions is 5.2 percent; but the *Spalax* lineage is only 40 million years old—and 5.2 percent in 40 million expands to 13 percent in 100 million years.) Moreover, *Spalax* has changed four amino acids at positions that are absolutely constant in all other vertebrates studied—seventy-two species ranging from dogfish sharks to humans.

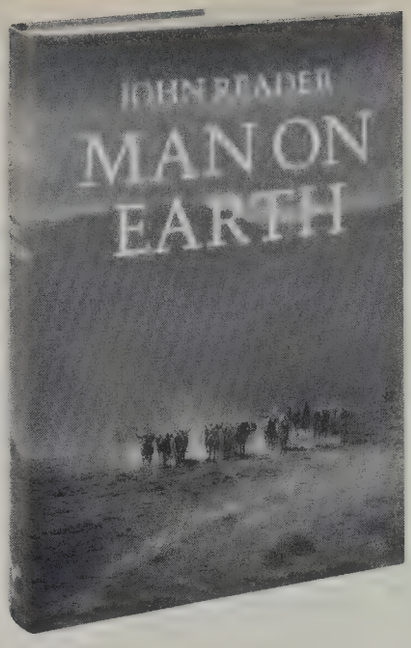
"These findings," Hendriks and colleagues conclude, "all clearly indicate an increased tolerance for change in the pri-

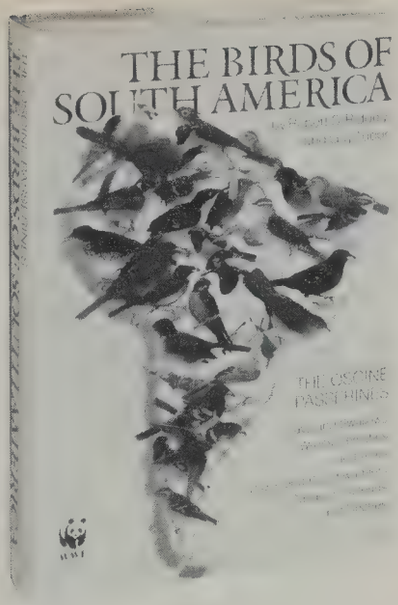
mary structure of αA-crystallin in this blind animal." So far so good. But the increased tempo of change in *Spalax*, though marked, still reaches only about 20 percent of the characteristic rate for pseudogenes, our best standard for the maximal, truly neutral pace of evolution. Thus, *Spalax* must still be doing enough with its eyes to damp the rate of change below its maximum for neutrality. The simple models of randomness have taught us something interesting and important—by setting a testable standard, approached but not met in this case, and acting as a primary criterion for judgment.

What then is αA-crystallin doing for *Spalax*? What can a rudimentary and irregular lens, buried under skin and hair, accomplish? We do not know, but the established intermediate rate of change leads us to ask the right questions in our search for resolution.

Spalax is blind, but this rodent still responds to changes in photoperiod (differing lengths of daylight and darkness)—and apparently through direct influence of light regimes themselves, not by a consequence (increase in temperature due to more daylight hours, for example) that a blind animal might easily recognize. A Haim, G. Heth, H. Pratt, and E. Nevo ("Photoperiodic effects on thermoregulation in a 'blind' subterranean mammal," 1983, *Journal of Experimental Biology*, volume 107, pages 59–64) showed that *Spalax* would increase its cold weather adaptation when exposed to a winterlike light regime of eight light followed by sixteen dark hours. These mole rats were kept at the relatively warm temperature of 22° C, and were therefore not keying to winter from clues provided by temperature. Animals exposed to twelve light and twelve dark hours at the same temperature did not improve their thermoregulation as well. Interestingly, animals exposed to summerlike light regimes (sixteen light and eight dark), but at colder temperatures of 17°, actually *decreased* their cold-weather adaptation. Thus, even though blind, *Spalax* is apparently using light, not temperature, as a clue to changing its physiology for the cycle of seasons.

Hendriks and colleagues suggest a possible explanation, not yet tested. We know that many vertebrates respond to changes in photoperiod by secreting a hormone called melatonin in the pineal gland. The pineal responds to light on the basis of photic information transmitted via the retina. *Spalax* forms a retina in its rudimentary eye, but how can the retina, which perceives no light in this blind mammal, act in concert with the pineal gland? But





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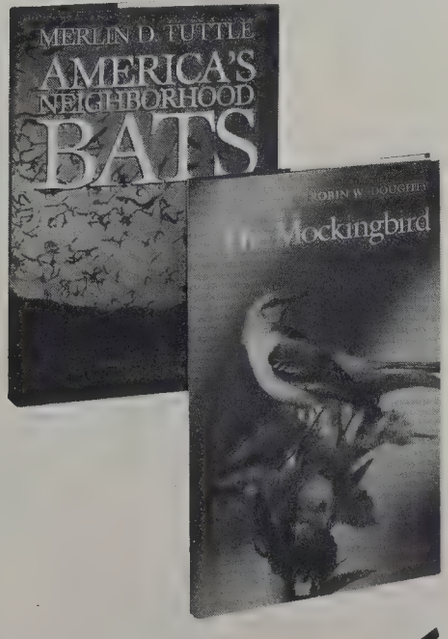

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Hendriks and colleagues note that the retina can also secrete melatonin itself—and that the retina of *Spalax* includes the secreting layer. Perhaps the retina of *Spalax* is still functional as a source of melatonin or as a trigger of the pineal by some mechanism still unknown. (I leave aside the fascinating, and completely unresolved, issue of how a blind animal can respond adaptively, as *Spalax* clearly does, to seasonal changes in photoperiod.)

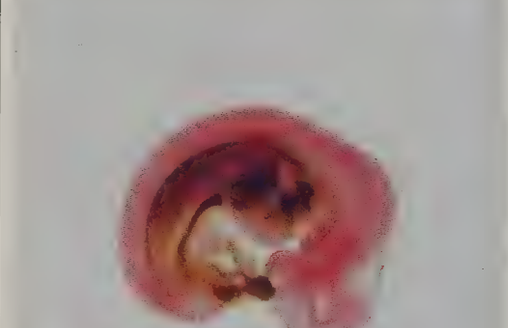
If we accept the possibility that *Spalax* may need and use its retina (in some nonvisual way) for adaptation to changing seasons, then a potential function for the lens, and for the αA-crystallin protei may be sought in developmental pat ways, not in direct utility. The lens canno work in vision, and αA-crystallin focuse no image, but the retina does not form i isolation and can only be generated as pa of a normal embryological pathway tha includes the prior differentiation of othe structures. The formation of a lens vesicl may be a prerequisite to the constructio of a retina—and a functioning retina ma therefore require a lens, even if the len will be used for nothing on its own.

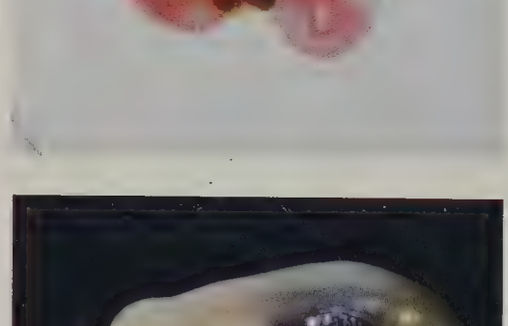
Evolution is strongly constrained by th conservative nature of embryological pro grams. Nothing in biology is more com plex than the production of an adult verte brate from a single fertilized ovum Nothing much can be changed very rad ically without discombobulating the em bryo. The order of life, and the persistenc of nearly all basic anatomical design throughout the entire geological history o multicellular animals, record the intricac and resistance to change of comple developmental programs, not the perfec tion of adaptive design in local environ ments. The intermediate rate of change i lens proteins of a blind rodent—a tempo so neatly between the maximal pace fo neutral change and the much slower rate for functioning parts—may point to a fea ture that has lost its own direct utility bu must still form as a prerequisite to later and functional, features in embryology.

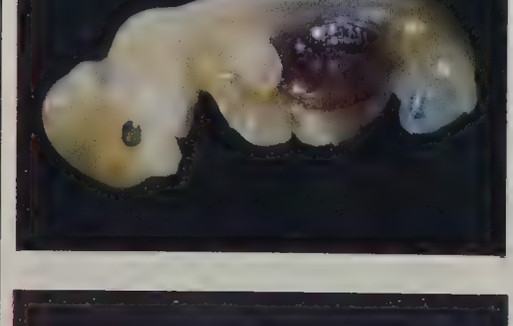
Our world works on different levels, bu we are conceptually chained to our own surroundings, however parochial the view We are organisms and tend to see the world of selection and adaptation as ex pressed in the good design of wings, legs and brains. But randomness may predomi nate in the world of genes—and we might interpret the universe very differently i our primary vantage point resided at this lower level. We might then see a world of largely independent items, drifting in and out by the luck of the draw—but with little islands dotted about here and there where selection reins in tempo and embry ology ties things together. What, then, is the different order of a world still larger than ourselves? If we missed the different world of genic neutrality because we are too big, then what are we not seeing be cause we are too small? We are like genes in some larger world of change among species in the vastness of geological time. What are we missing in trying to read this world by the inappropriate scale of our small bodies and minuscule lifetimes?

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

Progressive stages, top to bottom, in the development of a pig embryo (actual sizes, 6 mm, 21 mm, 35 mm) illustrate the complexity of "the production of an adult vertebrate from a single fertilized ovum."







Arthur M. Siegelman

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Room Without a View

Until a curious biologist dipped into its home, a tiny fish led its quirky life in well-hidden secrecy

by D. Scott Taylor

Counting angels on the head of a pin is easier than counting mosquitoes. Infestations are traditionally measured by landing counts: some poor sap stands still for one minute and counts all the mosquitoes trying to bite. Not a nice job, but somebody has to do it, so there I was, hot, tired, and sweaty, and I had lost the count at 118 with twenty seconds to go. This one will have to go down in the books as 100 plus, I thought, and resumed walking through the mangrove swamp, the viscous mud sucking greedily at my boots and threatening to pull them off with every step. I was thankful for the sparse shade of the mangrove trees above me on this mid-September day and even for the rivulets of sweat pouring off my body, theoretically keeping me cool and possibly drowning some of the mosquitoes trying to bite me. Not only was I hot, I was frustrated. I had spent most of the summer trying to track down the breeding site of the salt-marsh mosquitoes, the ones that were swarming over my exposed skin. I knew that time was running out and that I had probably missed my last opportunity to solve the mystery.

The tide in the Indian River Lagoon—the long, brackish estuary that runs almost the entire length of Florida's east coast—had risen sharply in the last week, flooding mosquito breeding marshes, and then it had suddenly dropped, but not before putting off a horde of the pests. The tide would probably come up again any day, remain elevated for several weeks, and curtail further mosquito breeding. My chances of finding the origin of my nemesis would be finished for the year. Another round won by the insects, I thought bitterly. I whacked at the brush with my mosquito dipper, a long-handled ladle used for sampling mosquito larvae, and then halfheartedly scooped up a dipperful of the only visible water in a small depression at my feet. Sure enough, no larvae, but four small fish darted frantically through the muddy water in the dipper. An oddity, I thought, as this area had no direct connection with the estuary, except during extremely high tides, and no permanent standing water. A second, careful look confirmed that the fish were unknown to me, but ever curious about fish, I put them into a bucket.

By the end of that long day in the mangrove swamps of east-central Florida, my thoughts were more on the strange fish than on my failure as a mosquito sleuth. Of the nearly ninety species of fish recorded from salt marshes in the Indian River Lagoon, about the only one I had never seen, alive or preserved, was the rare *Rivulus marmoratus*. I had a vague memory of its appearance, and the more I thought about it, the more convinced I was that riding back to the office with me were four rivulus. A quick check of a taxonomic key when I arrived confirmed my suspicions.

I stayed up late that night, trying to learn what I could about the fish. This species, it seems, was unknown to science until 1880, when two specimens were described as a new species by the Cuban ichthyologist Felipe Poly. It was not discovered in Florida until 1958, and since then it has been reported from various points in the Antilles and Central and South America. Although wide ranging geographically, nowhere is rivulus abundant. The fish is classified as a "Species of Special Concern" in Florida, and I was shocked to learn that fewer than fifty specimens had been reported on the east coast of the state, for fish, one of the most intensively collected areas in the world.

A member of the killifish family (Cyprinodontidae), rivulus is a small (less than three inches long), cryptic, mottled brown fish. A large eyespot, or ocellus, is prominent on the base of the tail, and this feature distinguishes it from look-a-likes in this large, minnowlike family.

Outside of its rarity, rivulus's real claim to fame lies in its unusual sex life: the species is hermaphroditic, that is, individuals produce both eggs and sperm internally and lay fertilized eggs that hatch into exact clones of the parent. This trait was first described in 1961 by the late Florida ichthyologist Robert Harrington, and descendants of the original clones produced in his laboratory are still cloning away in labs throughout the world. While hermaphroditism is not unknown among fish, rivulus is the only fish, and indeed the only vertebrate, to retain the characteristics of both sexes throughout its reproductive life. Interestingly enough, a few collectors have found pure male fish, differing from hermaphrodites by lacking the ocellus and having a red-orange tint to the fins and body. The function of the male is unknown, as sexual reproduction has never been documented.

An organism that clones itself and reproduces readily in small laboratory aquariums, as rivulus does, naturally has attracted the attention of geneticists, immunochemists, and the like, and the fish has been poked, prodded, and had its chromosomes split by white-coated technical types all over the world. But huge gaps existed in our knowledge of rivulus; although well scrutinized in the laboratory, practically nothing was known of its behavior and life history in the salt marshes and mangrove swamps it inhabits. The rubber-booted, mosquito-bitten ichthyologists had missed this one. Then and there, I resolved to fill in some of these gaps in the ecology of this rare and elusive fish.

The next day saw me back at the mangrove slough that had yielded my four specimens. Squatting down, I peered intently at the hole I had so casually sampled with my dipper and saw immediately

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D. Scott Taylor

Rivulus marmoratus, *a member of the killifish family, in an aquarium*

that it was a burrow of the great land crab, *Cardisoma guanhumi*. Fresh claw marks and fecal pellets outside the burrow indicated that the crab was in the burrow. Making a quantum leap in sampling technique, I gingerly inserted a small dipnet into the mouth of the water-filled burrow. I expected to feel the excruciating pain of a well-planned crab attack on my hand but instead pulled out five wiggling rivulus. Several more dips with the net yielded eight more fish. I was stunned; I knew that seventeen rivulus was a new single-point collection record for the species. I returned the fish to their burrow and went back to my office to ransack my library again, this time to bone up on the great land crab.

Cardisoma is a large, blue-gray terrestrial crab found throughout the tropical Americas and as far north as central Florida. Like their cousins the aquatic crabs, land crabs have gills that must be kept moist. They dig their burrows in soils in or near salt marshes and mangrove swamps, and in some cases several miles inland along freshwater tributaries. Burrows are dug to the depth of ground water, sometimes several feet deep at higher elevations, and the crab uses the water that collects in the burrow to moisten its gills. Crabs roam freely above ground to scavenge for vegetation and occasional bits of carrion. They molt inside the burrow and before doing so will seal themselves inside with a plug of mud and remain there until the new carapace is hardened, often a period of some months.

I thought it more than accidental that I found rivulus in a crab burrow, and I set about investigating this possible relationship further. I developed a stoop from hours of stalking marshes head down, checking for crab holes, but I was amply rewarded. During the next two years, with the patient tolerance of my bosses, I collected and released nearly 500 rivulus, all from land crab burrows. And this phenomenon does not seem confined to my part of Florida; I have obtained specimens from south Florida, the Florida Keys, and with the help of colleague Will Davis, from burrows of a related land crab, *Ucides cordatus*, in Belize, Central America. The association between crab and fish is unquestionable: in virtually every salt marsh that contained land crab burrows, I have been able to collect rivulus.

As with any art, my collection technique was refined as I went along. I soon realized that most burrows were not as easily sampled with a net as that first one; not only were many too small or twisted to accept the net, but the fish that I caught in this fashion were the smaller ones. For weeks I searched for an answer, and it

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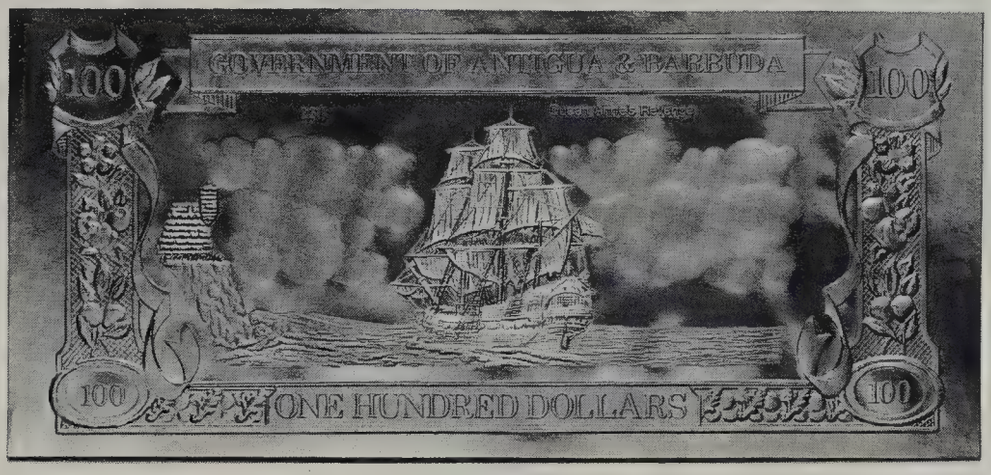

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finally came to me while searching my country-boy past. As a child, I used to spend hours in the Florida canals fishing for native minnows with a small stick, a thin fishing line, and a tiny hook baited with a small earthworm. The minnows would grab the ends of the worm and could be lifted from the water before they let go. I reasoned that since most killifish are voracious feeders and would probably be half-starved living in a crab hole, I would give it a try. My very first attempt met with success, and this has become my number one technique to this day. Fortunately for me, not too many people wander into salt marshes. I can imagine the sight I present: a grown man hunkered down in the mud, fishing in a crab hole, but at least I now have the all-tackle record for rivulus. My angling technique allows me to rapidly survey burrows for the presence of rivulus, but as with a mousetrap, a better one had to follow. A passive collection device was in order, so I designed a simple trap that could be inserted into a burrow. This consists of a twelve-ounce plastic drinking cup fitted with a small funnel held on with rubber bands and placed in the burrow, funnel down. Rivulus, which I suspect have to occasionally come to the surface of the burrow water to respire, enter the funnel and are trapped in the cup. This technique is effective and more scientific, but of course not as much fun as angling.

As I became more involved with these charming fish, I started to notice certain nuances of their behavior in the burrows. If I cautiously approached a burrow that I knew contained rivulus, I would often find one or more of them sticking to the sides of the burrow, but quick to jump back in the water at the slightest disturbance. This behavior, known as emersion, has been documented in the laboratory, but is not well known in the wild. Apparently, rivulus does this to avoid poor-quality water (and believe me, judging by the odors produced by land crab burrows, the water is of poor quality!). Rivulus has an extensive network of capillaries in the skin and fins that enables it to absorb oxygen when out of the water, and while emersed there is no gill movement. I had graphic evidence of the adaptive value of emersion on more than one occasion, when other species of fish had been stranded in crab burrows by receding tides. As they began to die and rot, I saw rivulus emersed on the sides of the burrow, simply waiting for conditions to improve. Even in burrows once filled with decomposing fish, I was able to find live rivulus after all traces of the dead fish were gone.

During the first months of my research

on rivulus, I was amazed that I could consistently find fish living in burrows that were only a few feet from permanent water. Given the marsh elevations at which I found most burrows containing rivulus, and the rhythm of tidal flooding throughout the year, I have concluded that most rivulus prefer to be confined to the burrows, except for the four-month period when the seasonal fall tides flood the marshes. On the other hand, I also had indications from field observations that fish were leaving the burrows when no standing water was available.

To further study the burrow behavior of rivulus I decided to design a special aquarium after the fashion of an ant farm, with a cutaway view of artificial crab burrows. I constructed a tall glass aquarium, packed it with the gooiest marsh mud I could find, and dug two burrows about eighteen inches deep along two sides. I completed the effect by adding mangrove leaves and transplanting small salt-marsh plants around the burrows. I filled the two burrows with water, added one rivulus to each burrow, and was entertained for a solid year by their antics. They began "burrow hopping" almost immediately, switching burrows at random, which required jumping out of the water and traveling with serpentine wiggles over several inches of damp mud. They seemed highly motivated in this behavior and would often switch burrows six or more times a day. To confuse the fish, I once placed a transparent plastic barrier between the two burrows and left only a half inch at the farthest corner of the tank. To switch burrows now required a roundabout route over a foot of dry ground, but sure enough, within two days they had solved the problem. I then closed the gap and drilled a half-inch-diameter hole at a completely different location along the barrier. Within twenty-four hours, they were through the hole and had resumed their traveling. To verify this behavior in the field, I dug artificial burrows within a few yards of crab burrows that I knew contained rivulus. I sampled these artificial burrows regularly during a period when the marsh was not flooded, and after a few months was able to collect rivulus from the fake burrows, an indication that in the wild the fish will travel over a damp surface to seek new habitat.

A further indication of rivulus's excellent adaptation to the burrow habitat was demonstrated in the late spring, a period of drought and very low tides in this part of Florida. I observed that many burrows that contained rivulus dried up completely, leaving only damp mud in the bottom. Nervously, I awaited a heavy

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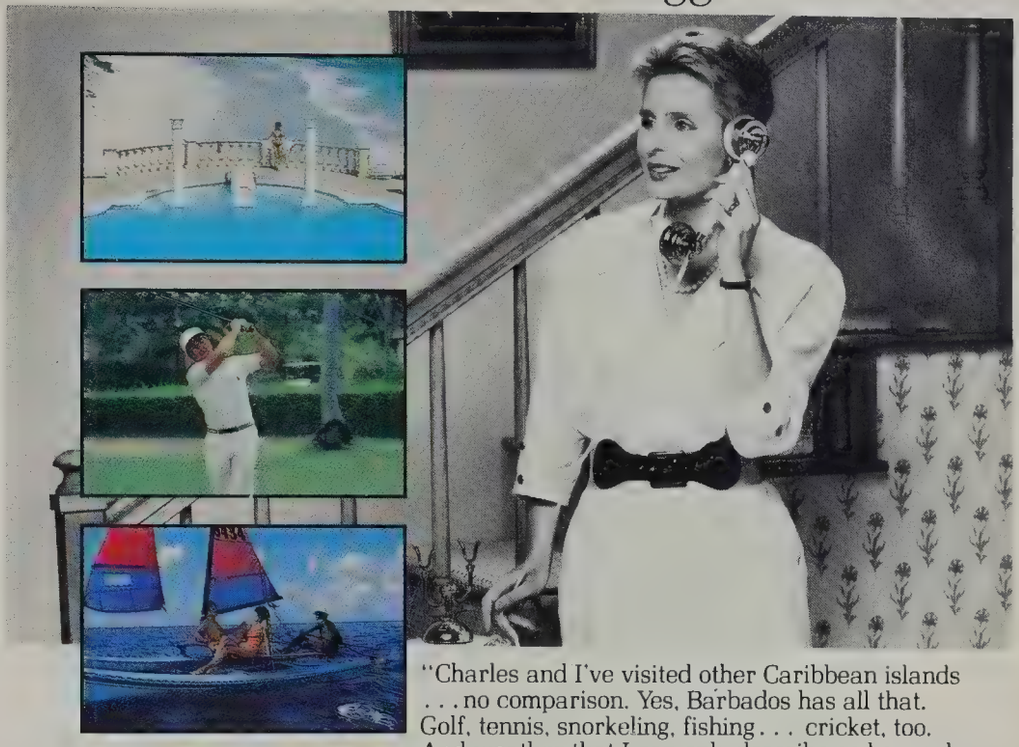

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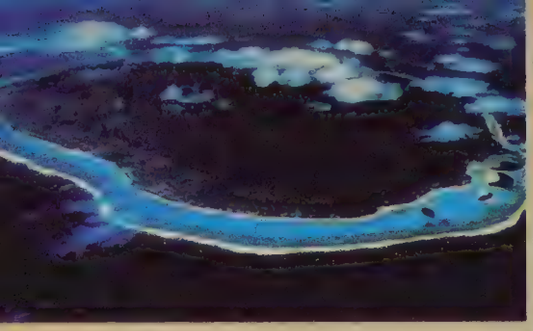

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rainfall and was pleased, but not surprised, to see the fish in the burrows again after they had refilled with water. To investigate this ability further in the laboratory, I constructed small artificial burrows in five large plastic containers. I filled the burrows with water, placed two fish in each container, and gradually lowered the water level in the burrows over a period of two weeks, leaving only the fish and damp mud. I then covered the containers loosely with plastic to prevent excessive drying and left them undisturbed, adding only enough rainwater to keep the mud damp. The fish promptly dug into the mud, and when the containers were reflooded after sixty-six days, eight of ten fish had survived and were feeding on mosquito larvae within ten minutes.

At this point, I wasn't sure if I was dealing with a fish or a salamander. What other surprises could these little creatures throw at me? There were still a couple left I had noticed that at certain times of the year many crab burrows were sealed, an indication that the crab was inside the burrow molting. I began tentatively to cut away the mud plug on some of these burrows and sample them for rivulus. Surely I thought, they couldn't survive up to several months of entombment. Wrong again: the third burrow I cut open yielded a thin but active rivulus, happy to see the worm I dangled in. In fact, later efforts at sampling sealed burrows produced my largest catch of fish from a single burrow a staggering twenty-six individuals!

The second big eye-opener occurred in my crab-hole aquarium. I had been puzzling from the very beginning of my involvement with rivulus about its reproductive habits in the wild. There was absolutely no information on this in the scientific literature, and I longed for some insights. My two crab-tank fish suddenly began to satisfy my wish. Eggs began to appear, sometimes five or six per day in the tank, not in the water as one would expect with a fish, but deposited on the damp mud, usually in the corner of the tank farthest from the burrows. I was thrilled enough at this but even more astonished to observe that the eggs could develop and hatch right on the damp mud. The young would manage to wiggle under a leaf, and the few that reached the water of the burrows were promptly eaten by the adults. Of course, this was no confirmation of the behavior in the wild, and I stepped up my search for rivulus eggs in the field. I was finally rewarded with the discovery of a single egg, found glistening on the wall of a burrow two inches above the water level. The question of where the bulk of the eggs are in the wild and where

the juvenile fish go remains: I have never captured a fish smaller than three-eighths of an inch long, and I suspect that the juveniles occupy an as-yet unidentified habitat. They certainly couldn't survive in the burrows with their greedy parent (notice the singular!).

When I describe my findings to others, I am almost invariably asked: "Why do you think a fish would choose to live in a crab hole?" or "Don't the crabs eat the fish?" The crabs, as noted, are vegetarians, and I think that generally rivulus does not interact with its ten-legged landlord. Under a dim red light at night, I have seen rivulus casually swim over and around a crab perched in the mouth of its burrow. As far as rivulus making a choice to live in a crab hole, the laws of evolution do not speak in terms of choices. Rivulus is basically a wonderfully adapted opportunist. Burrows offer a source of water that apparently no other fish can tolerate. Rivulus has no competition in this niche, which presents it with the unique opportunity to be the first fish on the "scene" when marshes flood. From the beginning of my interest in the fish, I have been bothered by the lack of a plausible explanation for its hermaphroditism. I suggest that this isolating habitat, the crab burrow, may explain the evolution of this reproductive character: if you live in isolated holes in the ground, your chances of finding a mate are not that good, so why not mate with yourself?

I feel very fortunate to have stumbled upon my discovery. Had I discarded that first dipperful of water without noticing the fish, or worse yet, assumed that they were a common species, I would have never been rewarded as I have. Although I realize now that rivulus is not as rare as was assumed, its tentative existence in salt marshes is so restricted and unusual that it is constantly in peril. Should we be protecting the fish or the crab? Land crab populations have been decimated in Florida's marshes by impounding and filling for development. No one can say how many rivulus have gone by the wayside as a result of these factors, and no one can say how many are left, but continuing and stringent protection of existing intact marshes is required. I would like to think that rivulus will always be out there lurking in the burrows, if only for the selfish reason that it will take me many more years to answer the questions I still have.

D. Scott Taylor is a marine biologist who loves salt marshes. He works as an environmental resources specialist for Brevard County Mosquito Control in Titusville, Florida.

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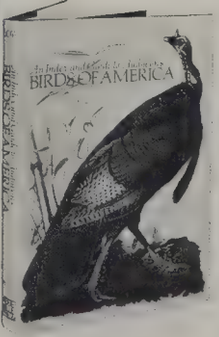

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Wyman P. Meinzer

"A timid desert creature that appears to be half bird, half reptile. But . . . watch him race across the sand, full speed, after a lizard. Watch him put out a wing, change his course, throw up his tail, change his course again, plunge headlong into a clump of cactus, and emerge, whacking his limp victim on the ground. Watch him jerk a slender snake from the grass, fling it into

by Robert D. Ohmart

the air, grasp it by the head and neck, pummel it with his hard mandibles, and gulp it head first. Watch him stalk a grasshopper, slipping quietly forward, making a sudden rush with wings and tail fully spread, frightening the doomed insect into flight, then leaping three or four feet in air to snatch it flycatcherwise in his long bill. Watch the roadrunner for an hour at his daily business of catching food and you will deem him among the most amazing of all the desert's amazing creatures."

Ornithologist George Miksch Sutton's 1940 description makes clear that the roadrunner runs for his supper. Sutton also recounts the apocryphal tale of the devious roadrunner building a fence of cactus spines around a sleeping rattlesnake, which on waking, thrashes about and finally impales itself. He gives some credence, however, to the story that these birds will lurk at a water hole and snatch airborne swifts that swoop down to drink. But when 99 percent of your prey is ground dwelling and frequents bushes, fluid, fast bipedal locomotion is the only way to travel.

Roadrunners range beyond the southwestern United States into California, Louisiana, and even the central plains of Kansas, but they reach their zenith in Arizona, New Mexico, and Mexico. In their center of distribution—the Sonoran and Chihuahuan deserts—roadrunners prey heavily on a fleet group of lizards, known as whiptails, that seldom venture far from the protection of bushes. While most large hawks lack the balance and quickness needed to capture these lizards, roadrunners have made whiptails a specialty.

Roadrunners have been clocked at fifteen miles per hour. (Over a short dis-

A roadrunner grasps the tail of a snake, below. Once the snake's head is exposed, the bird will dispatch it with a few precision blows of its beak and devour it headfirst. Roadrunners feed whole insects and reptiles, including small horned lizards, right, to their constantly hungry nestlings.

Both photographs by Wyman P. Meinzer

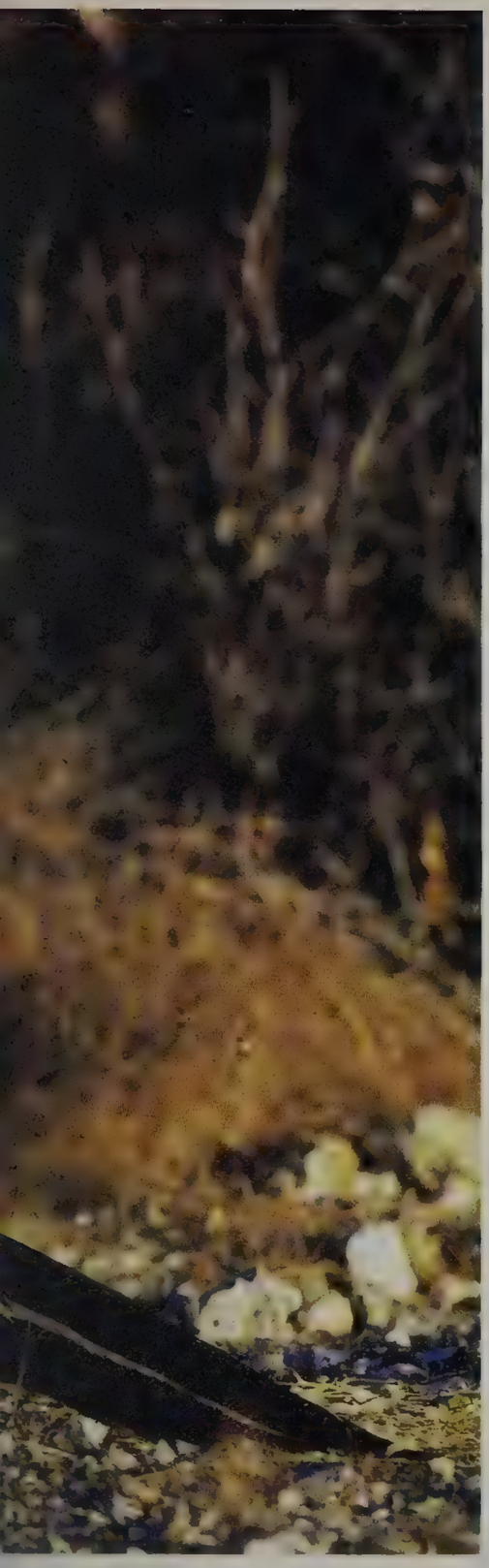
tance, a human sprinter can reach a rate equivalent to eighteen miles per hour.) Like many others, I have given in to the temptation to race a roadrunner, but even under the best field conditions, I could match its speed for only about one hundred yards. So roadrunners can maintain top speed for some distance. This speed and endurance has not gone unnoticed by the Tarahumara Indians of Mexico, themselves renowned for stamina and swiftness. One of their legends holds that by eating the flesh of a roadrunner the Tarahumara would acquire these qualities. The Hopi Indians of the Southwest also invest the spirit of the roadrunner with supernatural powers. Their kachina figures that depict the roadrunner are marked on the arms and legs with an X to represent the bird's distinctive two toes forward, two toes backward tracks. This symbol is used to ward off or confuse evil spirits, which are said to be unable to track the roadrunner because its direction of travel is never known.

Roadrunners belong to the cuckoo family, whose 127 species are distributed virtually worldwide. But terrestrial cuckoos, such as the roadrunner, are few and found only in South and Central America and into the middle latitudes of North America. I believe that about 100,000 years ago

early roadrunners took to the ground as descendants of tropical cuckoos that fed on easily accessible insects and fruits, making flight nonessential. Certainly by 12,000 years ago, ground-dwelling roadrunners had acquired all the skills needed to stalk, capture, and dispatch lizards and snakes. Then, as the glaciers of more northerly regions retreated, the Southwest became dry, and its wildlife was subjected not only to aridity but also to cold winter nights. While other birds of prey migrated seasonally, the opportunistic roadrunners thrived even in winter, when insects, lizards, and snakes virtually disappear.

Unlike some species of Old World cuckoos, which lay their eggs to be raised in the nests of other birds, roadrunners raise their own young and must run down enough prey to feed a brood that ranges from two to eight chicks. A typical pair of roadrunners mate for life and establish a permanent territory, the boundaries of which the male defends year-round. In spring, when days lengthen and the birds' hormone levels rise, a throaty song can be heard emanating from male roadrunners perched high in a tree or cactus. The bird begins to sing with its bill down, then raises its head toward the sky as it emits the last in a series of plaintive "coos." This posture prompted Mexican peasants to label the song of the roadrunner a morning prayer.

Twigs of about pencil diameter form the crude base of the plate-sized nest, which is usually situated well off the ground in a shrub, tree, or cholla cactus. A critical element in nest placement is access to shade and air currents, which are vital to nestling survival. After lining the nest with bark, hair, and finer twigs, the female begins her clutch; the final number of eggs laid appears to be correlated to the immediate food supply in the hotly defended territory. The female begins incubation immediately after laying the first egg. She sits mainly in the daylight hours,



A good roadrunner nest has both sun and shade. Heat-absorbing black skin warms nestlings, below, which in turn warm the eggs of their unhatched siblings when the parents are absent. When the young birds become too hot, they move to shady parts of the nest. An adult, left, restores its normal body temperature after a cold desert night by erecting the black, featherless "solar panels" on its back and basking in the sun.

Both photographs by Jeff Foott

while the male assumes the night shift.

The lengthy incubation period of seventeen days, with all the chicks hatching at different times, would seem to leave the young vulnerable to changes in weather and, consequently, in food supply. A couple of weeks with hot, dry winds and no rainfall can spell disaster for the youngest nestlings. I witnessed the energy-efficient roadrunner solution to this problem. At each nest visit the parent inspects the chicks by picking them up by the head or back and moving them around like chess pieces. When a nestling appears overly weak and lethargic, it is tossed into the air and swallowed whole by the adult. I observed this behavior at two different nests and frequently noted nests with one less occupant than on a previous day.

Adults must synchronize their hunting schedule with that of their primary prey. Whiptail lizards are active from about an hour after sunup until about 11:00 A.M. or noon. Parent roadrunners interrupt early morning hunting forays with brief stints at the nest to warm the nestlings and eggs. The chicks in turn help keep any nearby eggs warm. As the sun rises higher, the black, nearly downless nestlings absorb more and more solar radiation, stoking a body temperature of about 100° F. When a nestling gets too hot, it aligns its body, or sometimes just its head and neck, in any bands of shade crossing the nest. In addition, it dispels excess body heat by fluttering a membrane between its lower jaws and by excreting salts through glands near its eyes. Thus, nest placement and the nestlings' behavior and physiological adaptations allow the adults to concentrate their hunting activities when their prey are most active. Once it gets too hot for surface feeding, whiptails go underground, and one of the adult roadrunners begins shading the eggs and nestlings.

The roadrunner bill is not a shearing instrument, so lizards and snakes are brought in whole and fed headfirst to the nestlings. Frequently the prey is too big for the chick to swallow at one feeding. I have often watched a nestling slowly digest and swallow a large snake or lizard, the tail protruding from the chick's beak like a limp toothpick. Although roadrunners relish snakes and lizards, their diet is broad and includes ants, scorpions, tarantulas, centipedes, spiders, birds, small cottontails and other mammals to the size of wood rats, and seeds and fruits, including prickly pears. This catholicity is particularly valuable when winter temperatures make reptilian prey scarce.

To conserve energy on cold nights, roadrunners roost in dense trees or shrubs that shield them from the open sky and nocturnal winds. In addition, when not incubating they save body fuel by lowering their body-core temperature from about 101° to 94° F during the night. But the roadrunner morning sunning ritual is probably the most critical factor in conserving energy. The adults retain the black-pigmented skin of the nestling in a nonfeathered, H-shaped area on their back. Soft, black, downy feathers located around the pigmented area also absorb heat, but more importantly, they form a boundary layer over the black skin to prevent convective heat loss when the bird is sunning.

Sunning has been reported in many

Roadrunners pair for life and renew their bond each spring. A male, below, raises his crest and streamlines his plumage as he begins a courtship display. A male offers a kangaroo rat during copulation, right. Females usually snatch such nuptial gifts before mating is completed.

Both photographs by Jeff Foott

kinds of birds, but I am unaware of any species whose use of solar energy is more efficient. When a roadrunner with lowered body temperature leaves its roost at sunrise, it will sun in any windless spot; if a breeze arises, the bird will shift to a sheltered location. Its lowered body temperature can thereby be elevated to normal levels with little, if any, use of stored body fuels. Once a normal level is achieved, the bird can vary heat intake by adjusting feathers and essentially run the furnace on solar energy until temporarily scarce prey begins to move about and feed. I have watched birds sun for two to three hours at a time; they always keep their back perpendicular to the sun. After warming up, a roadrunner may maintain a lookout for a careless mouse that stayed out too late or a low-flying bird that can be snatched nimbly from the air. If no prey makes an appearance, the bird can simply reactivate the solar heater and bide its time until the few available lizards and insects emerge to feed.

The roadrunner's sophisticated survival tactics belie its reputation as the "desert clown." After a sleepy, basking roadrunner has harvested *el sol*, it will align its feathers and once more become a metallic green bullet slamming across the desert floor in search of its next meal. □

Photographs by David Hall

A giant sea anemone on a reef in Papua New Guinea

Sexual Stunts of Clownfish

by Daphne Gail Fautin

When a predator threatens the tiny clownfish, the colorful fish takes refuge among the tentacles of its sea anemone home. Most fish will not give pursuit because the anemone's tentacles are lined with stinging cells that fire harpoonlike projectiles and toxin into the intruder's flesh. The unwary fish that brushes against the tentacles and triggers the stinging cells is quickly paralyzed and slowly conveyed by the tentacles into the anemone's mouth.

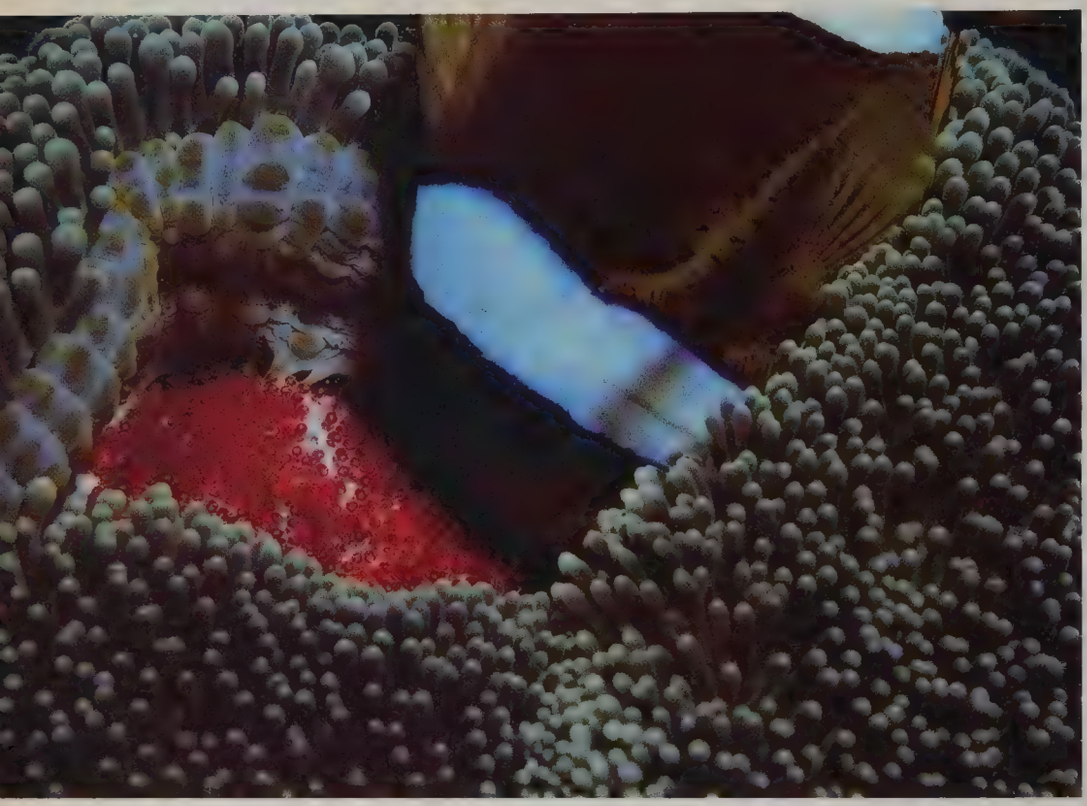
The clownfish, however, has evolved an effective immunity to the anemone's deadly toxin: its mucous coating fools the anemone, which fails to recognize the fish as foreign. As a result, the chemical and physical triggers that fire the stinging cells are not activated. How the clownfish gets its protective layer—secreted from itself or borrowed from the anemone's own coating—remains unanswered.

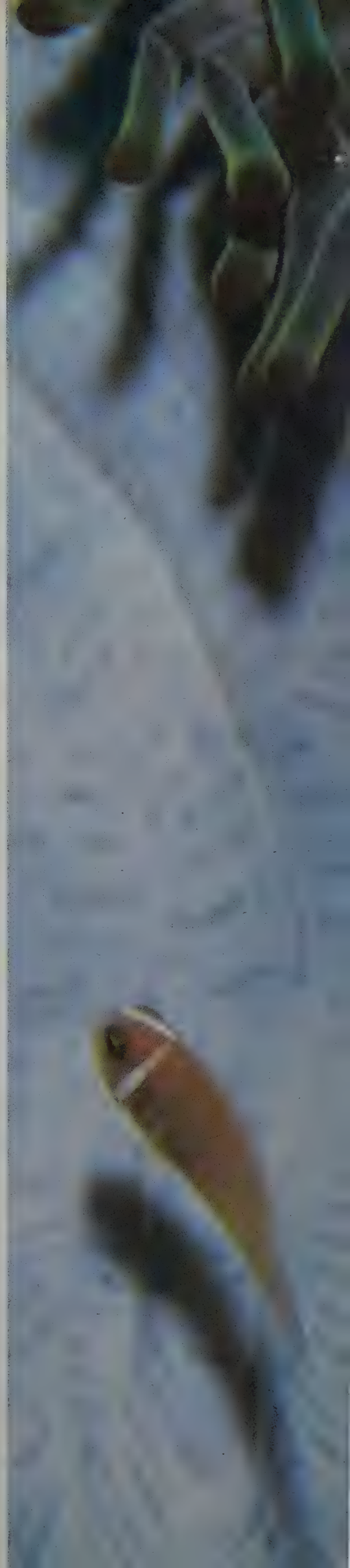
Confined to the tropical waters of the Indian and western Pacific oceans, the twenty-six species of clownfishes are rarely found more than a few feet from a sea anemone. A clownfish released away from its home swims as if it is disoriented, and lacking the speed and defenses that other reef fish have evolved, it is usually snapped up quickly by a predator.

Because clownfishes are restricted to 10, out of about 800, species of anemones, only a limited number of habitats are available to them. Clownfishes inhabit some of the largest, with a diameter often exceeding three feet. Most anemones are host to as many fish as can be accommodated, so clownfish populations are controlled by the number of hosts. When a fish finds a space on one, it does not leave; marked individuals have been seen year after year living on the same anemone.

The clownfish that claim an anemone are usually all of the same species. The largest fish is a female, the next largest a male, and the two form a monogamous breeding pair. In addition, one to six sexually immature clownfish also occupy the

A male barrier-reef clownfish, below, tends a clutch of eggs at the base of an anemone on Marion Reef in the Coral Sea. Right: An adult pair and a juvenile pink clownfish swim alongside a sea anemone in Papua New Guinea.





anemone, depending on the species of fish and the size of the anemone. The juveniles range in size from large to tiny and grow almost imperceptibly in lock step, maintaining their relative sizes. Somehow the development of the juveniles is arrested until the hierarchy changes.

The female lays several hundred eggs on a spot that has been cleared by her mate at the base of the anemone. The male protects, cleans, and fans oxygenated water over the eggs. Orange when laid, the eggs acquire a silver sheen as the eyes of the larvae develop. After about two weeks, the larvae hatch at night and disperse, drifting in the ocean currents. The female may lay another batch of eggs immediately or may wait as long as a week, giving the male a rest from his paternal duties. Breeding occurs continually in the equatorial tropics, becoming more seasonal with increasing latitude.

During its first few weeks as a larva, a clownfish is presumably carried far from its parents, and therefore the likelihood that a juvenile in an anemone is the offspring of the adult pair is very small. How a larval clownfish locates its own anemone after two or three weeks of growth in the plankton remains unknown. In addition to pure chance, a larva may home in on chemicals given off by the anemone.

Finding a suitable home, however, is not just a matter of locating a suitable anemone; it must be one with a vacancy. During the course of my research on a reef near Madang, Papua New Guinea, I never saw a small fry settle into an anemone, except when I created a vacancy by removing one of the resident fish. If an anemone is fully occupied, the residents will chase away newcomers of their own species as aggressively as they will defend their home from other species of clownfish. Should a young clownfish fail to find a home rapidly, it has little chance of survival.

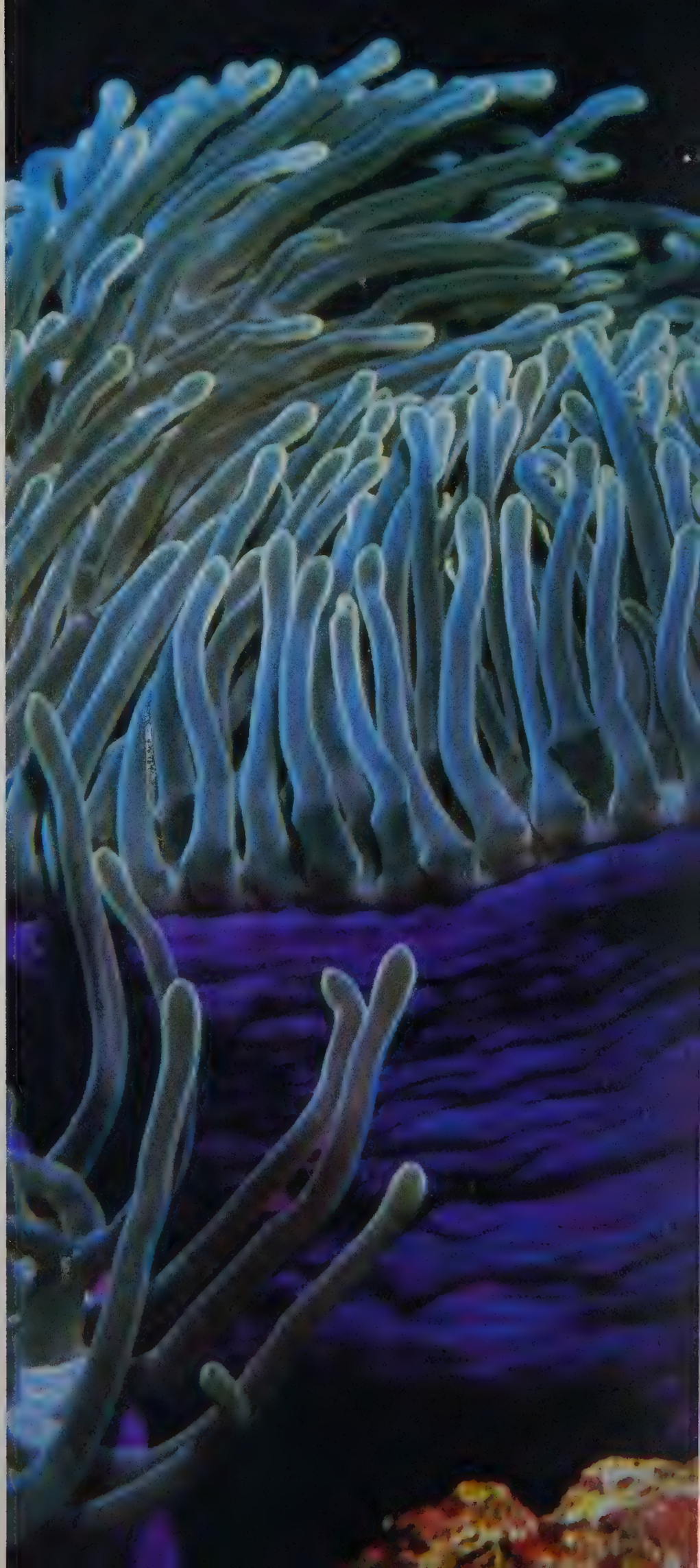
Wondering what happens when a mat-

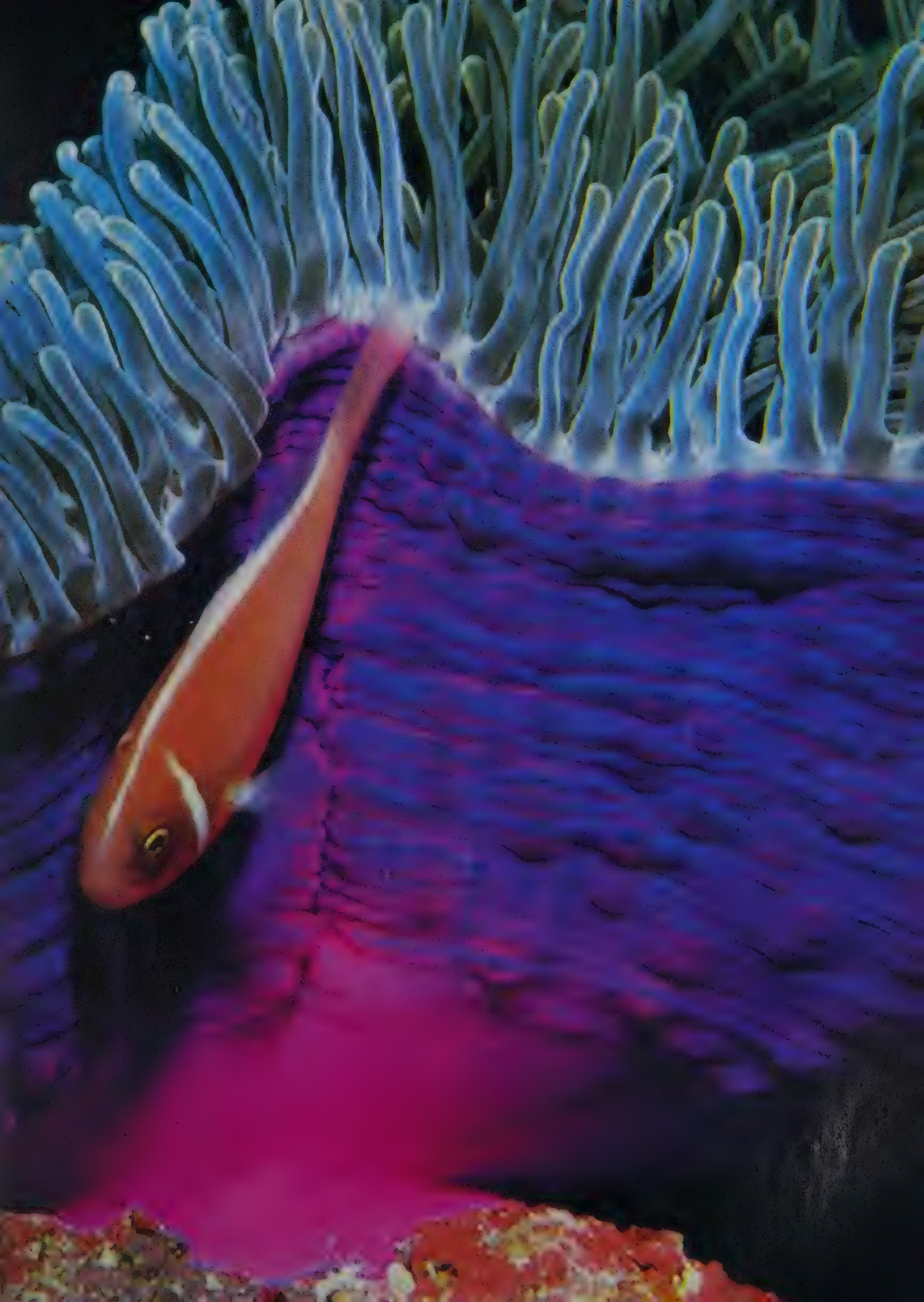
A pink clownfish in the Solomon Islands

ing pair are disturbed, I removed a male clownfish from his anemone. A month later, the largest juvenile had matured sexually into a male and was attending the freshly laid eggs he had fertilized. He had grown nearly as large as his predecessor. Moreover, each of the remaining juveniles had grown somewhat. And a tiny fish, fresh from the plankton, had just moved into its new home.

When I removed the female from an anemone, all the remaining fish grew, filling in the spaces, and a new one had settled at the bottom. But instead of the largest juvenile becoming a female, it became a male. The male clownfish changed into a female. The male's behavior altered within days, but the physiological changes that allow it to lay eggs took a few months. This pattern of sexuality, beginning reproductive life as a male and later becoming a female, is known as protandrous hermaphroditism and is rare among reef fish. The females cannot change into males, called protogynous hermaphroditism, a more common pattern among reef fishes. My current research is aimed at finding out if a juvenile fish can turn directly into a female or whether it must function first as a male.

Because they are restricted to a small territory around a single anemone, sex change makes sense for clownfish. Should one of a mating pair fall victim to a predator or die of old age, the remaining fish cannot swim off in search of a mate nor is one likely to arrive. Without the ability to change sex, the surviving mate would not only have to wait for a larval fish of the appropriate sex but also for it to reach reproductive maturity. Instead, a relatively large juvenile can fill the void, regardless of the sex needed, and reproduction can resume with a minimal loss of time. Furthermore, the new mate has already proved its ability to survive; each clownfish probably occupies its anemone for several years before it gets the opportunity to mature sexually. □





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Based on a drawing by Joshua Reynolds, an engraving depicts Outacite, Ostenaco, and Ushesees, Cherokees who traveled to London in 1762. Ornaments similar to the metal gorgets around their necks have been discovered by archeologists exploring the lower valley of the Little Tennessee River.

Smithsonian Institution

Strawberry Fields, Almost Forever

Generations of prehistoric Native Americans transformed the landscape of eastern Tennessee

by Jefferson Chapman, Hazel R. Delcourt, and Paul A. Delcourt

In the summer of 1776, upon entering the headwaters of the Little Tennessee River, naturalist William Bartram enjoyed a captivating view:

A vast expanse of green meadows and strawberry fields; a meandering river gliding through, saluting in its various turnings the swelling, green, turfy knolls, embellished with parterres of flowers and fruitful strawberry beds; flocks of turkies strolling about them; herds of deer prancing in the meads or bounding over the hills; companies of young, innocent Cherokee virgins, some busy gathering the rich fragrant fruit, others having already filled their baskets, lay reclined under the shade of floriferous and fragrant native bowers of Magnolia, Azalea, Philadelphus, perfumed Calycanthus, sweet Yellow Jessamine and cerulean Glycine frutescens, disclosing their beauties to the fluttering breeze, and bathing their limbs in the cool fleeting streams; whilst other parties, more gay and libertine, were yet collecting strawberries, or wantonly chasing their companions, tantalising them, staining their lips and cheeks with the rich fruit. The sylvan scene of primitive innocence was enchanting.

Bartram's florid prose conveyed an image of "noble savages" living in harmony with natural surroundings. The landscape he viewed, however, was actually far from primeval. Working along the lower thirty-three miles of the Little Tennessee River, not too far from where Bartram stood, archeologists and paleoecologists have documented 12,000 years of continuous human occupation that modified the environment.

The "Little T" is one of the principal tributaries of the Tennessee River. From its headwaters 4,500 feet up in the Blue Ridge Mountains of western North Carolina and northeastern Georgia, it flows northwestward, becoming a white-water river as it sweeps through a narrow gorge in the Great Smoky Mountains. Emerging from the mountains at an elevation of 815 feet, the river enters the territory of what were called the Overhill Cherokee, that is, those who lived beyond the mountains. Here, the Little T flows through its broader, lower valley, cutting across the gently rolling ridges of the Great Valley of eastern Tennessee until it joins the Tennessee River.

The changing relationship between Native Americans and the land they lived on is chronicled in the terraces that rise beyond the banks of the Little T. Each pair of terraces is the remnant of a floodplain formed when the river flowed relatively gently through the lower valley, occasionally flooding its banks and depositing layers of sand and silt. Swifter waters subsequently cut through these deposits, leaving a terrace on each side of the river. The process was repeated several times.

Altogether, the Little T has nine floodplains that were abandoned as the stream cut to lower levels.The oldest terraces lie along the flanks of the valley about 100 feet above the modern floodplain. Exposed the longest, their iron-rich sediments are oxidized a brick red. The most ancient terrace may be several million years old. Others were apparently deposited during changeovers from cold, glacial intervals to warmer periods. This occurred periodically during the last Ice Age, the Pleistocene, which lasted from about 1.8 million to 10,000 years ago. During glacial times, freezing and thawing shattered exposed layers of bedrock on the crests and steep flanks of Appalachian peaks above 4,500 feet. The resultant rock debris remained on the mountain slopes, however, stabilized by permafrost, subsurface soil frozen throughout the year. During the warmer interglacial periods that punctuated the Ice Age, the frozen ground thawed. Water-saturated soil and rock moved down the steep slopes from the Blue Ridge Mountains into the Great Valley, accumulating in the floodplains of such streams as the Little T.

The sediments of the youngest terrace border the modern floodplain. They contain fragments of wood and other organic matter that are from 15,000 to 3,500 years old, according to radiocarbon dating. This terrace is of special interest because these dates encompass the period for which archeologists have the earliest reliable evidence that humans penetrated North America south of Ice Age glaciers and thus could have entered the lower valley of the Little T. In fact, stone implements, human and animal bones, and hearths containing charred wood, seeds, and fruits

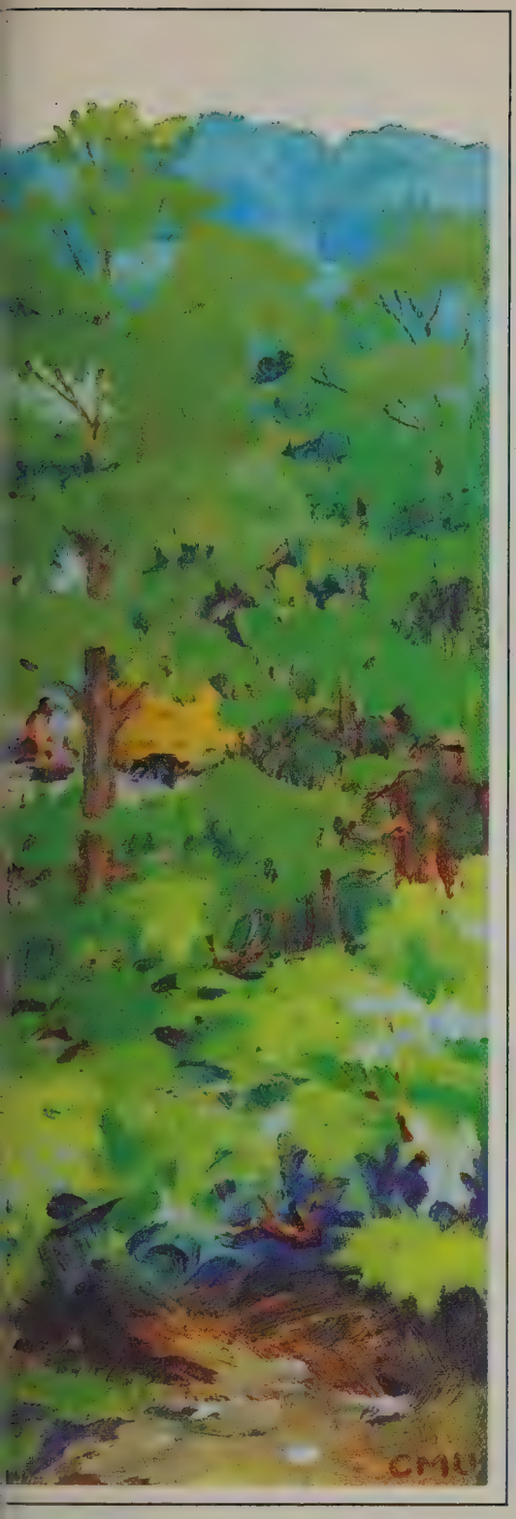
Carlyle Urello

lie deeply sealed within the layers of sand and silt of this terrace. These remains provide the best insight into early prehistoric occupation along the river. Early inhabitants also camped on the more ancient terraces and in upland areas, but there the artifacts lie on or near the surface, where they may be mixed with later materials and thus are more difficult to date.

Historic maps—such as one prepared in 1762 by a British lieutenant, Henry Timberlake—provide the general location of major Cherokee towns and other sites, some of which were inhabited in ancient times. For the most part, however, the key to interpretation of prehistoric events has been the thorough exploration of the modern floodplain and youngest terrace by archeologists, geologists, and paleoecologists from the University of Tennessee. This research was launched in 1967 in order to salvage the history of the land before construction of the Tellico Dam could flood some 16,500 acres of former Cherokee homeland. Jeff Chapman was one of several archeologists engaged in this massive effort.

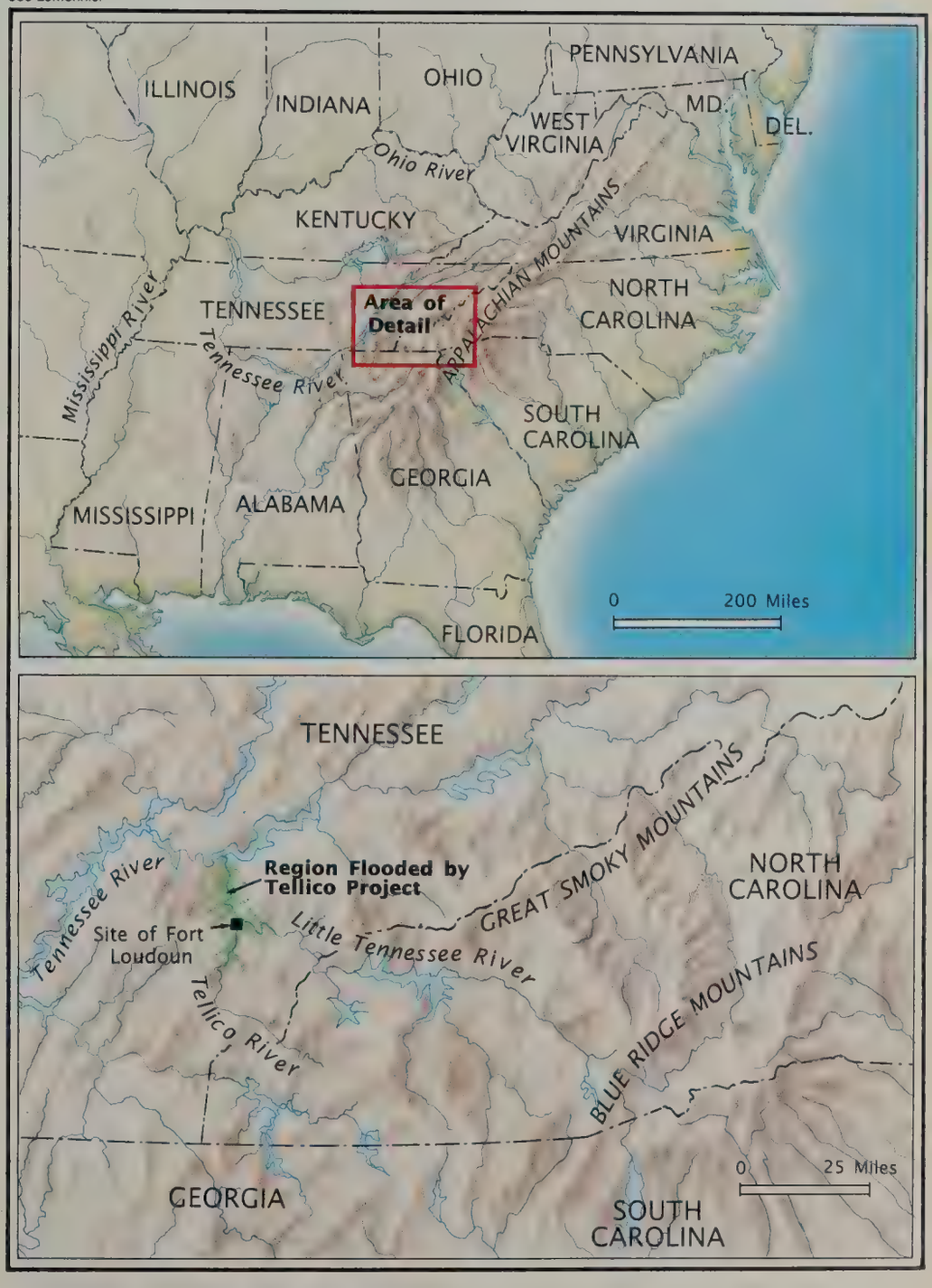
To find ancient sites we had to look on the land surface for such telltale remains as stone tools, pottery, and fire-cracked rock. Plowed fields revealed numerous clues, but in areas covered by dense vegetation, we plowed our own test grids, which from the air resembled large tick-tack-toe boards. We dug deep trenches with a backhoe at each promising location to confirm the presence of long-buried campsites. Archeologists then painstakingly removed the topsoil and underlying floodplain deposits. Their efforts revealed ancient habitations, as evidenced by layers of charred wood, post holes for house-frame timbers, fragments of clay daub used as wall chinking, and storage pits that once contained plant foods. They washed soil through window screens of different-sized meshes to recover fragments of stone, pottery, and bone.

To isolate botanical remains, soil samples were placed in a wire-bottom tub and immersed in water; fragments of carbonized plants that floated to the surface were skimmed off with a tea strainer and dried. Ethnobotanists Andrea Shea and Patricia Cridlebaugh then weighed, counted, and identified the carbonized material. Altogether, they examined more than thirty



During the Archaic period (10,000 to 2,800 years ago), hunters and gatherers occupied Icehouse Bottom, a site favored for its proximity to chert used for stone tools. This reconstruction shows the lower valley of the Little T about 9,000 years ago, when the Indians built camps directly on the floodplain. Periodically, the river overflowed its banks, burying artifacts and dwelling foundations in silt. Today, the lower valley, maps below, lies under the waters of a lake created by Tellico Dam.

Joe LeMonnier



pounds of wood charcoal, consisting of some 35,000 individual fragments, and seventeen pounds of charred fruits and seeds. Radiocarbon dating of carbonized plant materials from hearths and storage pits located at each level enabled us to correlate people's changing use of plants and animals with changing styles in such hunting and cooking implements as stone spearpoints and clay pots.

Occasional finds of fluted stone spearpoints or their fragments show that prehistoric people arrived in the Little Tennessee River Valley about 12,000 years ago. At the time, the landscape was forested with a mixture of conifer and hardwood trees and inhabited by mastodons and other large Ice Age animals. The Paleo-Indians, as archeologists call the earliest Americans, hunted game and gathered plant foods, most likely creating temporary and seasonal campsites. No such sites have been discovered, however; possibly rare to begin with, they may have eroded away.

Life styles became more sedentary along the Little T by about 10,000 years ago, marking the beginning of what archeologists call the Archaic cultural period. Descendants of the Paleo-Indians established residential camps on islands, sand bars, and backswamps built up by the Little T. Such camps were often located near raw materials, for example, chert nodules used for making stone tools. They included several households, each centered around a hearth, which was frequently made of red clay carried in from the uplands.

The camps were periodically buried by new layers of silt and sand as the river

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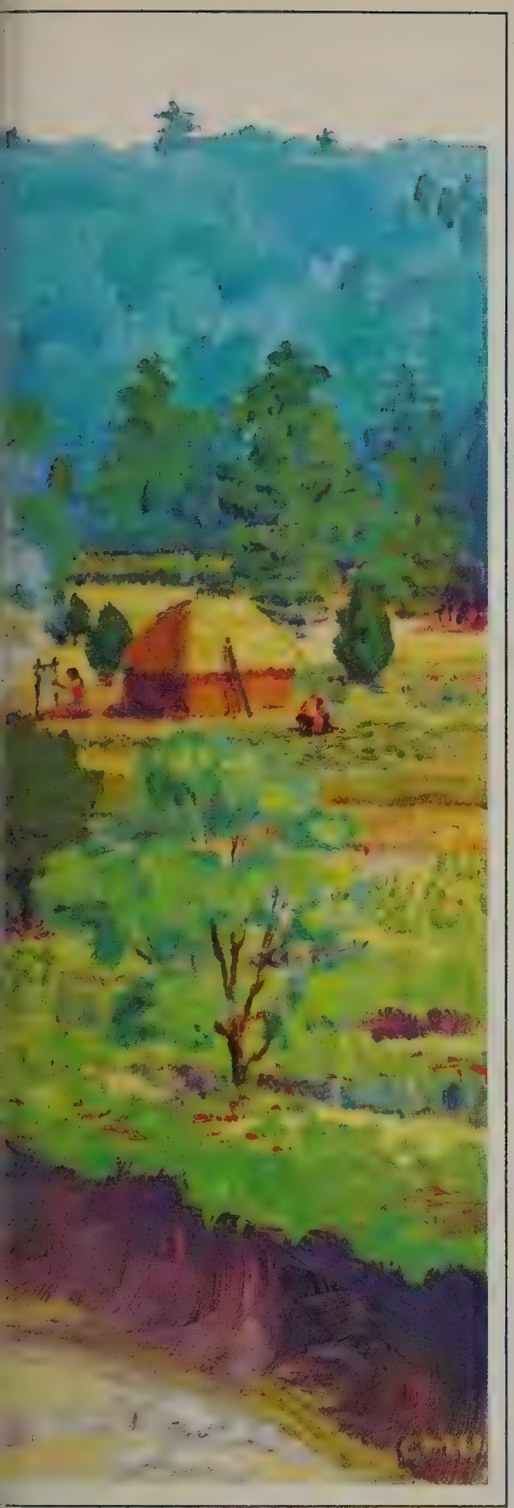
flooded. Over time, remnants of numerous Archaic camps accumulated in the river deposits. When excavated, some sites were like layer cakes of prehistory. Six places in the lower valley revealed especially long Archaic sequences; each may have been the territory of a different band of people.

During the early Archaic cultural period, people typically made triangular spearpoints with serrated edges and corner notches. These points were designed for hunting with the spear-thrower, a stick that helped launch the spear with greater force and accuracy. Wild plants rounded out a diet of game, fowl, and fish. Archaic people probably ate the young shoots of pokeweed as a green vegetable, as well as blackberries, strawberries, and wild cherries. Nuts were an important fall and winter food, evident from the carbonized shells of hickory nuts, acorns, and walnuts found in hearths.

Squash rinds appear in Archaic hearths dating from about 5,000 years ago, raising the possibility that this is when people in the region began growing vegetables. More likely, they were exploiting a wild species that was a progenitor of later domesticated squash. Somewhat later, about 4,400 years ago, maygrass, a wild grass whose seeds are edible, was brought into the Little Tennessee River Valley. Maygrass was probably introduced from its native range, west of the Mississippi Valley or along the Gulf of Mexico.

The Little Tennessee River Valley was still completely forested 10,000 years ago. Oak, American chestnut, and hickory covered the uplands, while beech, maple, ash, hornbeam, and walnut flourished on the intermediate and lower terraces. Sycamore, river birch, and willow grew in a corridor on what was then the floodplain (now the youngest terrace).

Charcoal from Archaic hearths of the youngest terrace shows that the wood closest at hand—that of the bottomland trees—was used for campfires. About 4,000 years ago, an increasing proportion of this fuel came from such species as red cedar and Virginia pine, trees characteristic of new growth rather than of mature bottomland forest. This shift implies that mature bottomland forests were shrinking and the landscape was becoming more open. Based on this evidence, we conclude



During the early Mississippian period (1,100 to 700 years ago), the people living at Icehouse Bottom cultivated much of their food in garden plots. The river flowed through a deepened channel and rarely inundated the former floodplain. A pottery bowl with alternating human head and frog motifs, below, is from the late Mississippian cultural period, 700 to 400 years ago. Mississippian people, who depended heavily on corn agriculture, may have regarded the frog as a symbol of water.

W. Miles Wright; Frank H. McClung Museum, University of Tennessee

that Archaic people were beginning to transform their environment.

The archeological sites in the youngest terrace deposits bring the story down to about 3,500 years ago. At that time, the Little T rapidly cut through the existing floodplain, perhaps because the climate was getting cooler or because human land use triggered erosion. In any case, the modern floodplain then began to develop, and natural and cultural remains from 3,500 years ago onward lie sealed within its sediments. These remains, as well as those in surface deposits throughout the valley, enable us to trace events from late Archaic times into the colonial period and the present.

For archeologists, the introduction of pottery and the cultivation of native food plants in garden plots, which occurred in the lower valley of the Little T about 2,800 years ago, marks a transition to a new cultural period, the Woodland. These Indians were probably descendants of the previous inhabitants and continued to collect wild food plants such as hickory nuts, acorns, and berries. In contrast to their ancestors, however, they used and eventually cultivated a wider variety of herbaceous plants. Sunflower, amaranth, goosefoot, and marsh elder, in addition to maygrass, were all found in their settlements. The edible seeds of the marsh elder increased in size through the Woodland and into the subsequent Mississippian cultural period, demonstrating that humans were deliberately saving and planting the largest seeds, an important contribution to the process of plant domestication.

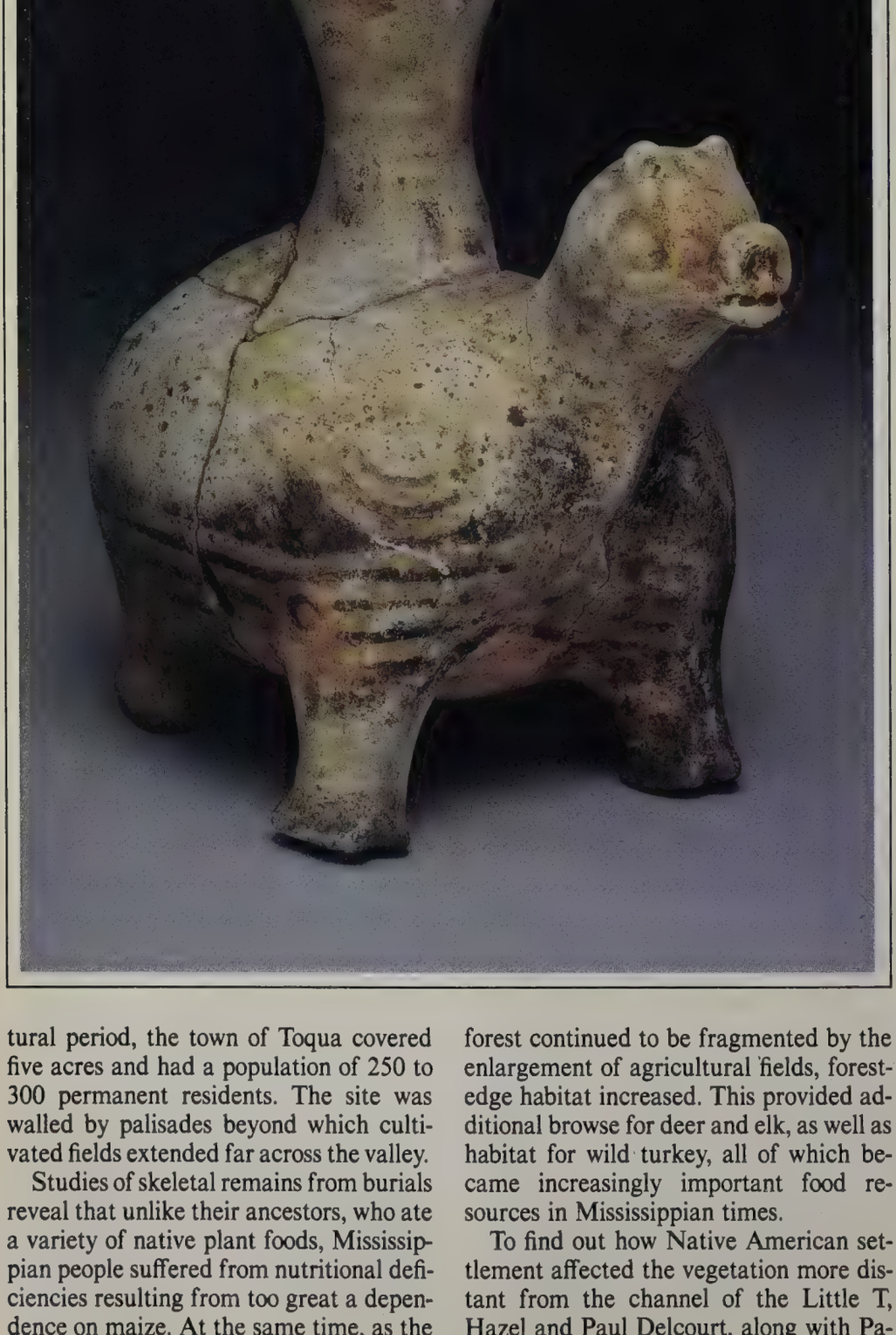
Many of the plant species that came under cultivation initially grew along the floodplain in such habitats as streamsides or rocky cliffs and probably first spread naturally into clearings near human encampments or where trees were pruned or cut for firewood. Other plants followed this pattern of expanding into areas disturbed by human activity but were not deliberately grown. Such plants are termed ruderals, or (more judgmentally) weeds. The shade-intolerant strawberry would have spread as a ruderal at this time, carpeting exposed stream banks and invading garden plots.

Among the materials recovered from one major site, Icehouse Bottom, is the earliest evidence of maize in the lower Little Tennessee River Valley. The oldest-known cultivated forms of maize, a domesticated type of teosinte, are from highland Mexico about 7,000 years ago, but the finds from Icehouse Bottom (radiocarbon dated by the accelerator method) show that maize was not introduced into eastern Tennessee until 1,775 years ago. It remained a minor constituent of the diet until about 1,100 years ago; then, stimulated perhaps by the development of new strains of the plant, local inhabitants began to cultivate large plots of maize to feed an expanding population.

The emphasis on maize was part of a change to a different pattern of living that archeologists term the Mississippian cultural period. Mississippian settlements included villages with platform mounds along the river and hamlets and farmsteads throughout the valley. During late Mississippian times, three villages became dominant: Citico, Toqua, and Bussell Island. Based on archeological remains, we estimate that by A.D. 1400, near the culmination of the Mississippian cul-

Cherokee Indians occupied Icehouse Bottom in historic times, continuing the Mississippian practice of corn agriculture. Their use of horses was one of the conspicuous results of European contact. A bottle in the shape of a dog, below, was interred with a young woman at Toqua, one of three indigenous villages that dominated the lower valley of the Little T in late Mississippian times.

W. Miles Wright; Frank H. McClung Museum, University of Tennessee



tural period, the town of Toqua covered five acres and had a population of 250 to 300 permanent residents. The site was walled by palisades beyond which cultivated fields extended far across the valley.

Studies of skeletal remains from burials reveal that unlike their ancestors, who ate a variety of native plant foods, Mississippian people suffered from nutritional deficiencies resulting from too great a dependence on maize. At the same time, as the forest continued to be fragmented by the enlargement of agricultural fields, forest-edge habitat increased. This provided additional browse for deer and elk, as well as habitat for wild turkey, all of which became increasingly important food resources in Mississippian times.

To find out how Native American settlement affected the vegetation more distant from the channel of the Little T, Hazel and Paul Delcourt, along with Patricia Cridlebaugh, collected fossil poller and larger plant remains from ponds or some of the older stream terraces and ir bedrock upland areas. The plant fossils could be expected to reflect changes ir vegetation both in the ponds themselves and in their surroundings within a one-mile radius. We examined sites from both sides of the river in the vicinity of Icehouse Bottom.

One site was Tuskegee Pond, located near the Cherokee village of Tuskegee—the birthplace of Sequoyah, who devised an alphabet for the Cherokee language. About one mile from the Little T, Tuskegee Pond was a shallow pool on an intermediate-level terrace. As much as six feet of sediments had accumulated in the pond just during the past 1,500 years—roughly

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corresponding to the period since the introduction of maize into the valley.

We cored Tuskegee Pond from a small raft, which was made of a plywood platform lashed over inflated neoprene boats and securely anchored. Starting at the surface of the sediments at the bottom of the pond, we thrust a stainless-steel corer, two inches in diameter, down to collect three-foot-long sections of sediment. The successive segments were extruded onto the raft, measured, described, and wrapped in plastic and aluminum foil.

In the laboratory, we took many small samples from along the length of the cores for pollen analysis. Because the cell walls of pollen grains are resistant to most acids, we were able to use such solvents to dissolve away mineral matter in the mud without harming the pollen. We then mounted the residue on microscope slides and counted the proportions of different types of pollen grains.

Pollen grains of maize are relatively heavy and large; even when blown by wind, they typically travel no more than sixty yards from the stalk that produced them. Maize pollen landed in the sediments of Tuskegee Pond continually for the past 1,500 years, showing that the pond was adjacent to permanent Indian cornfields. Other food plants represented in the Tuskegee Pond pollen record were goosefoot and marsh elder; fruits and seeds of blackberries and strawberries were also found.

Tellingly, between 30 and 55 percent of the pollen in 1,500-year-old samples of sediment from Tuskegee Pond was ragweed. Together with evidence of other ruderals such as carpetweed, as well as of the various food plants, the high proportion of ragweed shows that even in Woodland times the inhabitants were clearing not only bottomland but large portions of lower- and mid-elevation terraces as well. In contrast, many lakes studied by paleoecologists elsewhere in eastern North America indicate no more than a 5 percent ragweed count until *after* European settlers arrived and caused major deforestation.

In the Tuskegee Pond sediments we also noted a growing frequency of vegetation fires (measured as influxes of charcoal particles) and a rise in erosion of local hill slopes (indicated by greater accu-

Archeologists found many spearpoints and arrowheads in the lower valley of the Little T. The large one shown below is a Paleo-Indian (Clovis) spearpoint, used by the earliest humans to enter the region. The others are, left to right: (top row) Cherokee cut brass arrowhead, late Mississippian arrowhead, late Woodland or early Mississippian arrowhead, and early or middle Woodland spearpoint; (bottom row) late, middle, and two early Archaic spearpoints. A notice issued by the U. S. government in 1838, opposite page, closed the books on 12,000 years of indigenous life in the lower valley of the Little T.

W. Miles Wright; Frank H. McClung Museum, University of Tennessee

mulation of sediment). Such increases coincided with major changes in culture and technology. For example, during the transition from Woodland to Mississippian, the proportion of charcoal particles increased, possibly because a growing population was setting more hearth fires or because fire was used as a tool to keep the understory of upland forests open for hunting game.

Pollen analysis of a second site, Black Pond, on the uplands across the river from Tuskegee Pond, showed that the higher terraces and bedrock uplands were less affected by prehistoric land occupation and cultivation than were the lands close to the floodplain. Black Pond contained about nine feet of mud rich in organic matter and dating from the past 3,000 years, thus embracing all cultural periods following the Archaic. These sediments reveal a forest of pines and deciduous trees from 3,000 years ago; ragweed remains scarce until about 400 years ago, the time of European settlement and the use of metal tools for widespread land clearance.

The Europeans came into contact with native people in the Little Tennessee River Valley as early as 1540, when De Soto led the first Spanish exploration of the interior of southeastern North America. De Soto's party apparently spent almost a week at Bussell Island. The Europeans carried diseases to which Native Americans were not immune, and many of the inhabitants died. The Overhill Cherokee who came to inhabit the lower valley of the Little T were probably not simply descendants of the local late Mississippian people but rather a blend of survivors and of incoming groups who had crossed the Blue Ridge Mountains from western North Carolina.

During the colonial period, Europeans introduced new crops, among them the peach and the watermelon. Peach pits are commonly found in Native American sites throughout this time; seventeenth-century accounts by English settlers in the Carolinas and Georgia describe peach trees growing both wild and in Indian orchards. Europeans also brought domesticated livestock, including cattle and horses (previously, Native Americans had only the domestic dog).

In addition, European settlers inadvertently introduced exotic weed plants such as clover, pinks, goosegrass, and plantain. Plantain (*Plantago*), an herb known for its medicinal properties since at least the time of Shakespeare, was called "white-man's foot" or "Englishman's foot" by Native Americans, who believed that it grew only where the English had trod. The European plants were better adapted than were the native species to the disturbances caused by the trampling and grazing of domesticated animals. After introduced diseases diminished Native American populations, invading plants crowded out many native herbs and shrubs in fallow Indian fields.

Finally, Europeans introduced iron axes and hoes. This new technology increased the farming capabilities of the Overhill Cherokee, but because the new farming methods facilitated land clearance, they also increased erosion of the topsoil. The pioneers themselves cleared great expanses of upland areas, as evidenced by a decrease in the ratio of tree pollen to that of introduced weedy plants.

In 1756, the British built Fort Loudoun on a terrace adjacent to the floodplain of the Little T, not far from both Icehouse Bottom and the town of Tuskegee. The fort was originally meant to protect the Cherokee from the French, and in return the Cherokee sent nearly 700 warriors to fight for the British in the French and Indian War. Relations between the British and Cherokee soon deteriorated, however, and the Cherokee laid siege to Fort Loudoun. In August 1760, the garrison surrendered and the fort was subsequently burned by the Cherokee. Retaliation by the British (and later the newly independent colonists), along with the continuing disease toll, nearly annihilated the Cherokee population in the area.

A complete removal of southeastern tribes of Native Americans began in the late 1700s, and finally in 1838, under U. S. government authority, the Cherokee were evicted from their homeland and forced along the Trail of Tears to the Oklahoma Territory. For the past 150 years, the lower valley of the Little T has been occupied by European-Americans, who have raised dairy herds and corn on a nearly treeless landscape. The final episode of disruption was completion of the Tellico Dam in 1979 by the Tennessee Valley Authority. With that, water flooded much of the homeland of the Overhill Cherokee, inundating the strawberry fields forever. □

MAJOR GENERAL SCOTT, of the United States Army, sends to the Cherokee people, remaining in North Carolina, Georgia, Tennessee, and Alabama, this

ADDRESS.

Cherokees! The President of the United States has sent me, with a powerful army, to cause you, in obedience to the Treaty of 1835, to join that part of your people who are already established in prosperity, on the other side of the Mississippi. Unhappily, the two years which were allowed for the purpose, you have suffered to pass away without following, and without making any preparation to follow; and now, or by the time that this solemn *address* shall reach your distant settlements, the emigration must be commenced in haste, but, I hope, without disorder. I have no power, by granting a farther delay, to correct the error that you have committed. The full moon of May is already on the wane, and before another shall have passed away, every Cherokee man, woman and child, in those States, must be in motion to join their brethren in the far West.

My Friends! This is no sudden determination on the part of the President, whom you and I must now obey. By the treaty, the emigration was to have been completed on, or or before, the 23rd of this month, and the President has constantly kept you warned, during the two years allowed, through all his officers and agents in this country, that the Treaty would be enforced.

I am come to carry out that determination. My troops already occupy many positions in the country that you are to abandon, and thousands, and thousands are approaching, from every quarter, to render resistance and escape alike hopeless. All those troops, regular and militia, are your friends. Receive them and confide in them as such. Obey them when they tell you that you can remain no longer in this country. Soldiers are as kind hearted as brave, and the desire of every one of us is to execute our painful duty in mercy. We are commanded by the President to act towards you in that spirit, and such is also the wish of the whole people of America.

Chiefs, head-men and warriors! Will you, then, by resistance, compel us to resort to arms? God forbid! Or will you, by flight, seek to hide yourselves in mountains and forests, and thus oblige us to hunt you down? Remember that, in pursuit, it may be impossible to avoid conflicts. The blood of the white man, or the blood of the red man, may be spilt, and if spilt, however accidentally, it may be impossible for the discreet and humane among you, or among us to prevent a general war and carnage. Think of this, my Cherokee brethren! I am an old warrior, and have been present at many a scene of slaughter; but spare me, I beseech you, the horror of witnessing the destruction of the Cherokees.

Do not, I invite you, even wait for the close approach of the troops; but make such preparations for emigration as you can, and hasten to this place, to Ross' Landing, or to Gunter's Landing, where you all will be received in kindness by officers selected for the purpose. You will find food for all, and clothing for the destitute, at either of those places, and thence at your ease, and in comfort, be transported to your new homes according to the terms of the Treaty.

This is the address of a warrior to warriors. May his entreaties be kindly received, and may the God of both prosper the Americans and Cherokees, and preserve them long in peace and friendship with each other!

WINFIELD SCOTT.

CHEROKEE AGENCY, }
May 10, 1838. }

Some black bears, left, and timber wolves, below, find their way home over long distances.

Home, Sweet-smelling Home

Do bears "follow their noses" to find their way back?

Text and photographs by Lynn Rogers

The notion that mammals, including humans, might have a special homing ability has been around for a long time. Walt Disney's film *The Incredible Journey* portrayed the prodigious navigational powers of a lost dog and cat, but the movie and the book of the same name are entirely fictitious. In real life, most pets that get lost stay lost.

Occasionally, however, a dog or cat does something spectacular and unexplainable—like Snooky, the ginger tomcat that returned 135 miles from his new home in Gloucester, England, to his old home in Balsham in just twenty-two days. A white-tailed buck that was captured and transported 350 miles in Texas also seemed to know the way home. It took him nearly two years, but he somehow made it back to the Aransas National Wildlife Refuge on the Gulf of Mexico. And a female wolf that had spent her entire life in a pen in Barrow, Alaska, needed only four months to return home after she was released 175 miles away. Other examples abound. One involves an immature female deer mouse, probably only three or four months old, that was released two miles from her home in Wyoming. She returned in two days. Before that, she probably had spent her entire short life in an area of a few acres.

Nevertheless, scientists still question whether mammals truly possess a navigational ability akin to that of homing pigeons. True navigation implies the ability to orient homeward, or toward some other point beyond immediate sensory contact, from a previously unvisited area. This capacity differs from simple piloting based on familiar landmarks and from the ability to migrate in a particular direction without reference to landmarks. It requires not only a compass sense to determine direction but also a mental map to determine location relative to home or some other goal. The navigational ability of mammals is questioned because for each animal that comes home, dozens or thousands of the same species go in the wrong direction or just stay put where released. Scientific studies have not been convincing; the mammals that returned usually did so over short distances from release sites that may not have been beyond sound or smell of home. The anecdotal cases of spectacular homing over long distances usually lack the details that might provide simple explanations.

The wolf that returned 175 miles in Alaska, for example, may have homed in on the sounds of large jets at the Barrow airport near its pen. Jets can be heard for tremendous distances across the treeless tundra on still, cold nights, and the familiar sounds of the planes would have been focused toward Barrow from the wolf's location. A second wolf in that experiment moved to a different airport 100 miles in the wrong direction. Similarly, the deer that returned home 350 miles may have scented the Gulf of Mexico when moist breezes blew from the home direction. In all, seven deer returned home in that experiment, all moving at least eighty miles, while more than 8,000 others either went the wrong way or remained where released. A similar story may explain the homing mouse. The experimenters Olaus and Adolf Murie had been camping in the mouse's home range for most of its young life, and the sounds and smells of their camp and campfires on the quiet Wyoming mountain could have signaled home. The release site was directly downslope

A female bear had been moved forty miles away but she returned home to have cubs. Home territory provides known food resources and established social relationships with other bears in the area.

from camp, exactly where the campfire smoke would likely drift in the evening. Both the camp and the release site were along Whetstone Creek, which also could have guided the mouse. Aside from that mouse and a few others that returned to the camp in that study, homing by deer mice and other small mammals seldom exceeds a few hundred yards, approximately the distance one would expect the sounds and smells of home areas to reach.

Mice and other small mammals may not be the best subjects for homing studies. They normally do not travel far, and they have a consuming abhorrence of predators. When they find themselves in a strange place beyond sensory contact with home, they usually stay put rather than risk extensive travel where escape routes are unknown.

But bears are not overly concerned about predators and are not afraid to make diligent efforts to get home through unfamiliar country. They are among the land mammals most likely to show true navigational ability if it exists in a mammal. Black bears depend upon berry and nut crops that often fail, requiring them to make long searches into unfamiliar range and to return home through the same unfamiliar territory. In many instances the search route is wandering and circuitous while the return is direct, which means the bear must have a sense of place and a sense of direction.

Black bears that get in trouble raiding garbage provide great opportunities for testing navigational abilities. Wildlife managers, game wardens, and wildlife researchers in nine states and two Canadian provinces have trucked offending bears to remote areas, usually while the bears slept off tranquilizers. The bears were ear-tagged so if they were ever shot, recaptured, or sighted, the officials could learn whether they returned home or not. One hundred and fifteen (64 percent) of the 179 bears returned home. The question is: How do they do it? Are they familiar with huge areas? Do they wander randomly or in expanding search patterns until they find an area they know? Or do they use some means of navigation?

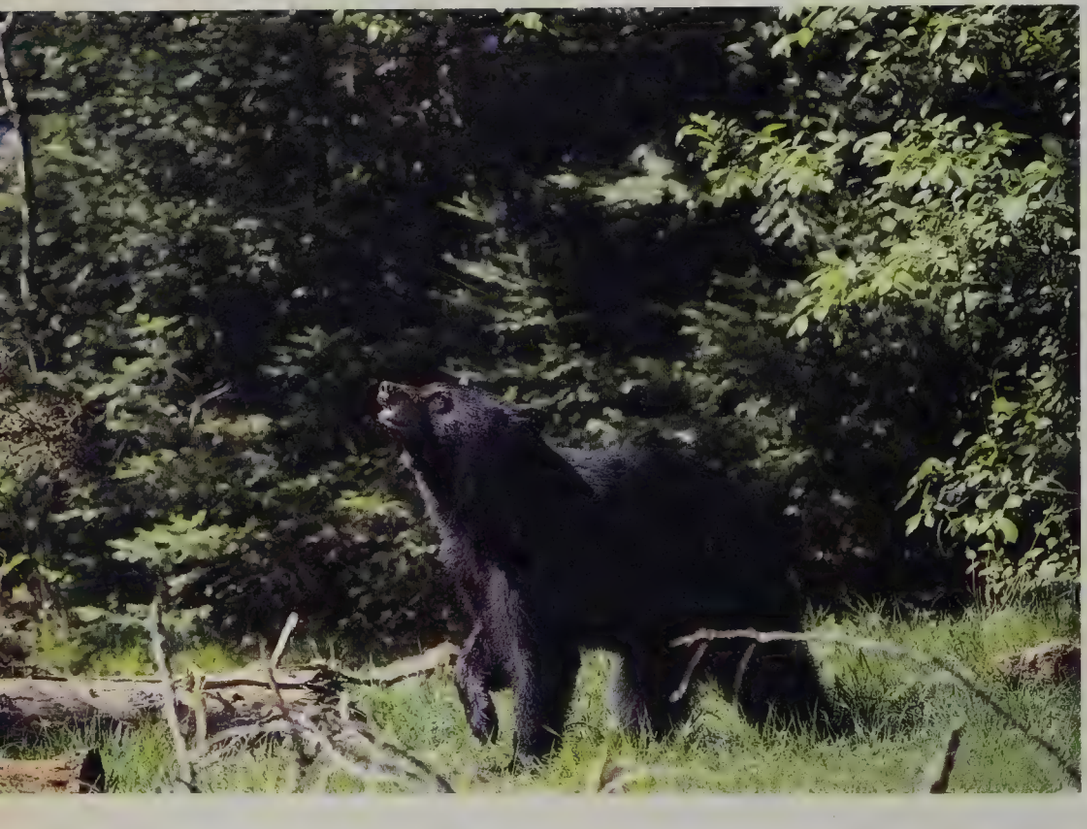
Bears that were moved only five to forty miles were probably released in familiar range or close enough to familiar range that random wanderings could conceivably account for homing. Of those bears, 81 out of 100 returned. But how many bears would be familiar with areas beyond forty miles? Not many, according to the results of twenty-two studies of bear movements. In seventeen of those studies, at locations across the continent, no bear traveled that far. In each of four other studies, only one bear traveled that far. Only in the less fertile forests of Minnesota did an appreciable number of bears travel forty miles or more, and most of those were young males making one-time moves from their mothers' territories their adult living areas. Young femal usually established living areas near the birthplaces and did not make the lo dispersal movements. Adults of both sex explored distant feeding areas, but on three journeys of more than 40 miles (5 57, and 126 miles) were recorded duri seven years in which the movements forty-eight adults and forty-five young bears were radio tracked.

Nuisance bears that researchers a wardens moved more than forty mil would be the ones that could reve whether black bears have any real navig tional ability. Since it is possible that ev

a few of those might be helped by familiar areas, the "more than forty mile" bears were divided into two groups for analysis: those that were moved 40 to 75 miles and those that were moved 75 to 169 miles. Since the latter would be less likely to find familiar areas, fewer of them would be expected to move homeward (if homeward orientation depends upon finding familiar areas). In fact, slightly more moved homeward from the greater distance. Bears that moved in the homeward direction, or within 22.5 degrees of it, included thirty-five (65 percent) of fifty-four bears from the first group and seventeen (74 percent) of twenty-three bears from the second group. Apparently, familiarity with the release area or vicinity was not the key to homeward orientation. Unfortunately, the rigors and dangers of strange country took their toll on the bears released at greater distances. Although more of them did head homeward, fewer of them made it. Half made it home from 40 to 75 miles away, and 30 percent made it home from 75 to 169 miles away. The rest gave up, were shot, or were hit by vehicles.

The longest successful homing was 142.5 miles by an adult female that El Harger, a research biologist with the Michigan Department of Natural Resources, moved in Michigan's Upper Peninsula. Another female that Harger moved 168.5 miles probably would have bettered that record if she had not been killed. For sixty days after release, this mother and her cub moved forty-three miles directly toward home. The cub was then killed on a highway. Traveling alone, the mother made fifty-five miles in the next six days until Keweenaw Bay in the Upper Peninsula interrupted her movements and funneled her along to the bay-tip town of L'Anse. Hungry after traveling so quickly through unfamiliar country, she peeked in a window on the outskirts of town and was shot. She had moved ninety-

A black bear, right, ears pricked forward, stares intently in the direction of an unfamiliar sound. By standing on its hind legs, the bear can not only see over the grass but can also intercept breezes carrying odors. Outside its own territory, a bear often behaves more cautiously—frequently checking out any new sights or sounds. A bear attempting to find its way home, below, probably uses several methods of navigation; sniffing the air for odors may play a major role.



eight miles toward home in sixty-six days.

I had long wanted to watch a homing bear on the move to see if I could learn anything about homing movements and directional cues. Big Mac, a radio-collared eleven-year-old that lived in northern Minnesota, gave me my only opportunity. A drought and berry crop failure had forced him 126 miles outside his usual range, the longest move outside an established range ever recorded for a black bear. He foraged south and west in a big meandering arc through forested terrain. When it came time to den up, he turned directly homeward, moving northeast through open farmland and residential areas rather than returning by the safer, more forested route. My assistant, Bob Hodorff, and I monitored his progress. We soon learned that he traveled only at night, moving as if on directional autopilot with little regard for terrain or obstacles. His route was so predictable that on the fourth night we parked where we anticipated he would cross a gravel road.

Our location was perfect. "Here he comes!" Bob whispered as Mac emerged from the forest and angled across the dark road toward our car. He plodded around the car and continued down the road a short way. The road nearly paralleled his route, and we wondered if he might use the curving road to get around the tangled patch of forest at that point. The road would have taken him perhaps twenty degrees off course. He chose the forest. "Right on course," said Bob as he listened to the bear's radio signal grow fainter.

During the next three days and nights the sky was so overcast that there was no sun by day and no stars by night. Wind and snow blew out of the northwest, creating a crosswind for Mac. Somehow he maintained direction and speed. Late into his ninth night of travel, Mac reached his usual range. His behavior changed. He began using the curving forest roads even though they took him a bit off course. He used well-worn shortcuts where available and unhesitatingly left a road to cross a river on rocks rather than on a shaky old bridge that was ahead. He seemed to know the easy routes, many of which were forest roads. He stopped to rest at dawn but resumed walking in midmorning. This was the first time he had been active by day since he began his return trip, although he normally was active by day in his established range. About noon he left a road, walked over a hill, and entered an old den—a rock crevice just big enough for his 450-pound body. Somehow he had maintained direction through more than a hundred miles of unfamiliar range, regardless of weather.

Studies of animal homing and navigation attempt to determine what senses and information animals use to form their mental compasses. Scientists speculate that magnetite in the heads of homing pigeons and other species, including some mammals, may serve as tiny compasses, but whether bears have magnetite is unknown. By whatever means, Big Mac showed an incredible sense of direction. He probably combined compass sense and memory to form a mental map during the outbound portion of his travels. But how do bears that are drugged and transported form mental maps when they awaken in a strange place?

Recent studies with pigeons suggest that the mental map may be based in part on odors. Italian researcher Floriano Papi studied the role of odors in pigeon homing and hypothesized that "pigeons, during their first months of life, would learn to recognize the odors prevailing in the area of the loft, but when the wind blows, they would also receive information about foreign odors from surrounding areas. At the same time they would associate the different foreign odors with the direction from which they came." In Italy, anosmic pigeons— those with an impairment or loss of smell— neither orient nor return home, although anosmic pigeons in other areas often do, showing the presence of more than one orientation system.

If an odor-based system works for pigeons, it should work even more efficiently for bears. The bears' sense of smell may be the keenest of any mammal in North America: they have an area of nasal mucous membrane a hundred times larger than that of humans. And their brains are the heaviest, relative to body length, of any carnivore. Also, their ability to store information is excellent. Cubs remember, as adults, locations their mothers showed them twenty miles away. An odor-based mapping system could explain why

bears that were transported far outside areas they conceivably could smell, such as bears taken from Minnesota to Arkansas (880 to 940 miles), didn't seem to have a clue about home direction. They moved in random directions up to 260 miles from release sites. Such a system may also be the reason that bears released in unfamiliar range often delay starting for a few days or weeks as if taking time to get their bearings, perhaps by smelling winds from different directions as weather patterns change. The learning process that would accompany the formation of mental maps, odor-based or otherwise, may explain why young bears seldom return home after being moved.

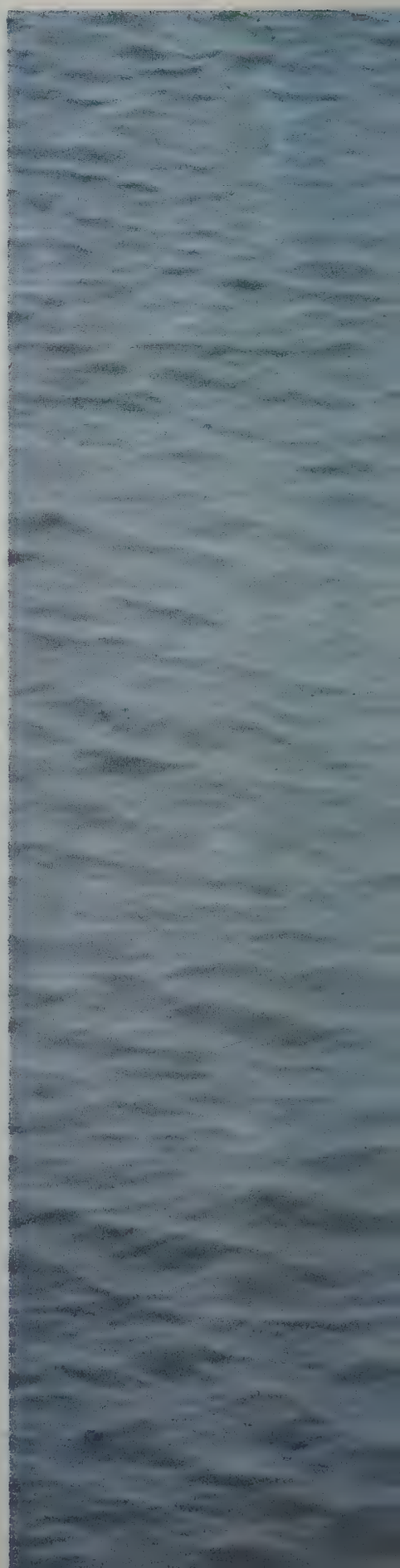
A second hypothesis regarding the formation of a mental map is that animals sense the more or less regular changes that occur in the earth's magnetic field. Pigeons may determine their location relative to home by extrapolating local gradients in magnetic field change. Considering the compass sense shown by Big Mac, this may also apply to black bear navigation. Anomalies in the earth's magnetic field could explain why some bears make false starts in wrong directions but, by using magnetic cues, eventually realize their mistake and head home.

The sensory abilities of black bears have not been fully explored. Studies of homing pigeons revealed abilities to detect polarized light, ultraviolet light, very low frequency infrasounds, and changes in atmospheric pressure. Which of these senses might be used to determine homeward direction and which might be shared with black bears is unknown.

Bears that were radio tracked filled in only a few details on homing movements. Most delayed starting. Some made false starts in wrong directions. Others moved directly home, zigzagged home, or settled somewhere else. An adult female that Gary Alt, a bear biologist with the Pennsylvania Game Commission, moved eleven miles in Pennsylvania, stayed within a few hundred yards of the release site for five days and then moved two miles in a wrong direction during the next four days, before moving directly home in two days. Alt watched an adult male for a few hours after moving it twenty miles. Three times he saw the bear stop, pivot several times, and start out toward home. However, the bear did not continue, so the pivoting may not have been related to homing. The bear remained within a few hundred yards of the release site for three days and then set out toward home, where it showed up three days later.

Black bears are not the only bears that have demonstrated homing ability. Among the few grizzly bears that have been moved is a four-year-old male that returned home over 160 miles in Alaska. Seven others traveled more than 125 miles. Polar bears currently hold the bear homing record of 300 miles. Three males and a mother with cubs all returned in fourteen to twenty-four days, moving twelve to twenty-one miles per day. However, the release site was probably familiar to them because it was on a commonly used migration route on the shore of Hudson Bay. Polar bear orientation and navigational abilities are of special interest because there are so few landmarks on the drifting, constantly changing ice. Could an odor-based orientation system explain how polar bears, in their frozen world of minimal odor, keep their sense of place well enough to maintain predictable home ranges from year to year? Possibly. The polar bear's Roman nose may be the keenest nose of all, and there is the possibility that magnetic cues are used, even at the high latitudes where these bears live. Polar bears and other bears probably use several orientation systems, just as people and homing pigeons do.

Bears provide the most compelling evidence for mammalian navigational ability. We now know that they do not rely on random wandering, expanding search patterns, or familiarity with large areas to find home. Whatever method of orientation they use, it apparently is effective for at least 169 miles. Odors and magnetic cues are possible sources of navigational information, but neither idea has been scientifically tested with bears. More systematic studies are needed. Bears, because they can carry radio collars, might unlock some of the secrets of animal orientation and navigation. □



A polar bear wades offshore in Hudson Bay before the annual freeze-up. Several polar bears have returned home over a distance of 300 miles, but the release site was probably familiar to them since it was along their regular migration route. Navigation among polar bears is of special interest because they travel in areas of minimal landmarks on the constantly changing ice.

Stephen Trimb

Brumley Ridge, Utah

by Robert H. Mohlenbrock

Known locally as the P–J zone, piñon and juniper woodlands make up nearly one-third of the forested land in the Rocky Mountains, generally occupying the elevations between 5,000 and 7,500 feet. Falling comfortably within these margins is Brumley Ridge, a 6,500-foot foothill in Utah's Manti-LaSal National Forest. To the west of the ridge, the land dips down to desert grasslands, while aspen and dark ponderosa pine forests cloak higher terrain to the east, leading up to the snow-capped 12,000-plus-foot peaks of the La Sal Mountains.

The species of the two small conifers that dominate the P–J zone—juniper and piñon pine, whose oily seed, the piñon nut, was a staple food for prehistoric inhabitants of the Southwest—differ from place to place in the Rocky Mountains. There are three types of piñon pines (true, single-leaf, and Mexican) and four kinds of junipers (Rocky Mountain, Utah, one-seed, and alligator). On Brumley Ridge, the true piñon pine and the Rocky Mountain juniper prevail.

The soil in the P–J zone is shallow and rocky; trees are scattered, and other vegetation is sparse. An occasional shrubby sagebrush, snakeweed, or Gambel oak breaks up the monotony, while patches of grasses—mutton grass, galleta, needlegrass, Indian ricegrass, and blue grama—grow where moisture accumulates.

Several kinds of cactuses dot the terrain. Once, while enjoying a leisurely hike east of Brumley Ridge, I chanced upon an eighteen-inch-wide clump of bluish green, succulent cactuses, dozens of two- to three-inch-tall plants crowded together. The most notable feature of this clump was that not a single spine was evident on any of the stems. Having studied the endangered species of the United States for several years, I knew immediately that this was the spineless hedgehog cactus, one of the rarest plants in the country.

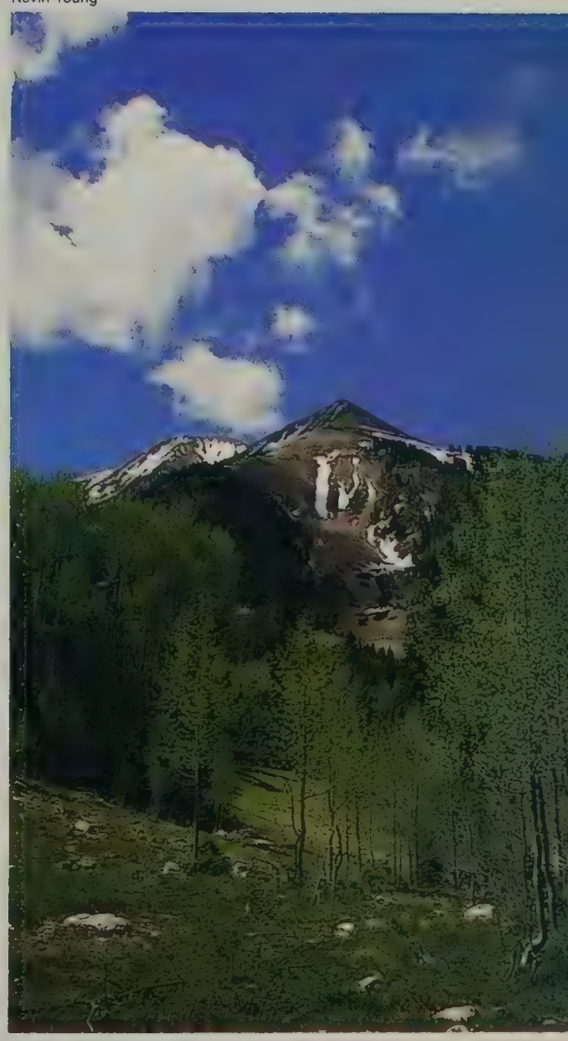
First discovered in the La Sal Mountains about 1895 by German botanist Joseph Anton Purpus, and also known in adjacent Colorado, the spineless hedgehog cactus has long puzzled botanists. Despite the plant's striking lack of spines, its flowers (the main feature that botanists examine for reliable distinctions) resemble those of the red claret hedgehog cactus, a common species that grows from California to Colorado to Texas and south to Mexico. The red claret hedgehog cactus is known to be a highly variable species (cactus authorities recognize eight or nine different varieties). Occasionally, too, a clump of spineless hedgehog cactus is found in which one or more stems bear a few spines, clouding the plant's only notable feature.

An important clue that two plants may differ genetically is that they grow in different places. As pointed out by cactus authority Lyman Benson, however, the spineless plants are scattered throughout populations of spined varieties in west-central Colorado and east-central Utah. And, although most varieties of the red claret hedgehog cactus grow in the open sun, while the spineless variety often grows in the shade of piñons and junipers, this too is not a clear-cut difference.

While at first glance spiny and spineless hedgehog cactuses appear to occupy the same areas, recently a team of botanists has noted that, on closer examination, they may actually grow in different microhabitats. The Colorado Plateau is an area of sedimentary rocks, such as sandstones and shales, whose erosion exposes many layers. As it turns out, where there is a series of ledges, the spineless plants grow on level tops and spiny plants occur on side slopes. Since the two varieties occur in nearly pure populations, these botanists feel that they are adapted to different conditions and to a degree are genetically isolated.

Several studies still need to be done to establish the taxonomic status of the spineless hedgehog cactus. A possibility yet to be excluded is that it is an "ecological form" of a spiny cactus—a growth pattern the plant follows wherever it is subjected to certain environmental conditions. To resolve this, attempts must be made to transplant some spiny cactuses to where the spineless types flourish, and vice versa. If such transplants fail, the plants are more likely to be distinct varieties. Analysis of the contents of the cells of the two types could also be made to see if

Kevin Young



Mount Tukuhnikivatz, as seen from Brumley Ridge. Opposite page: A rare spineless hedgehog cactus

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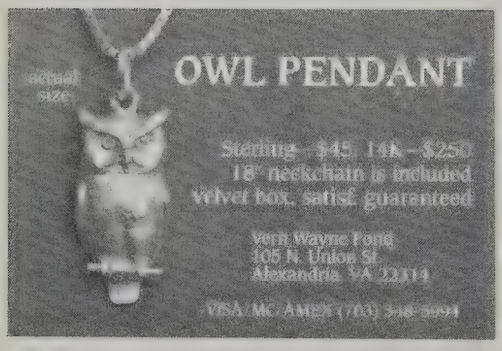
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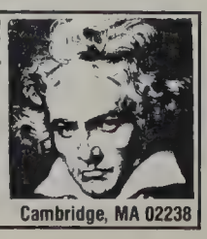

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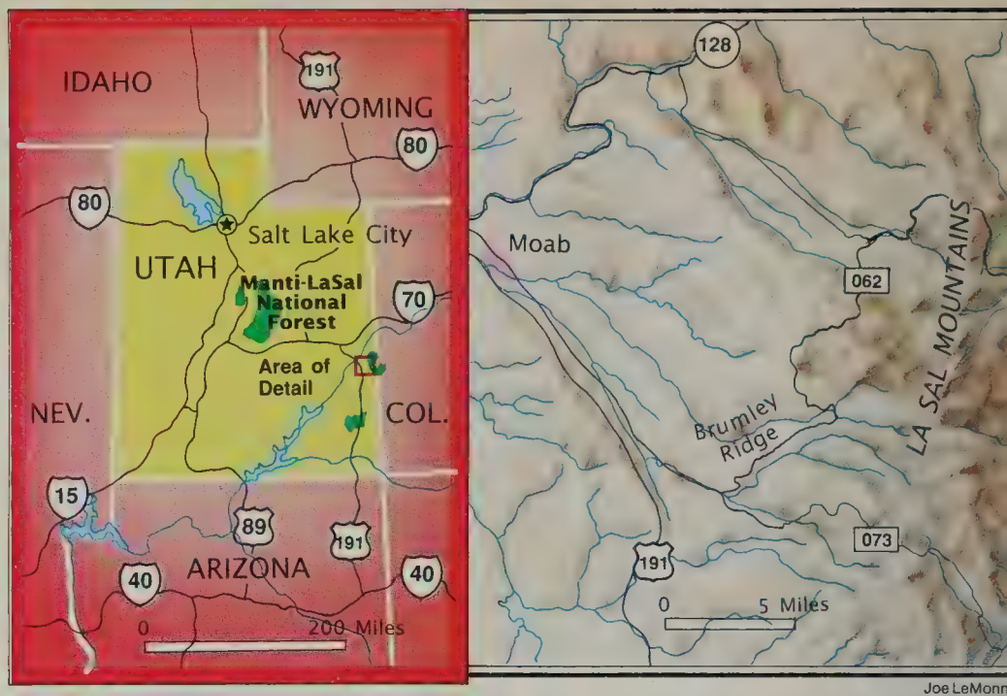
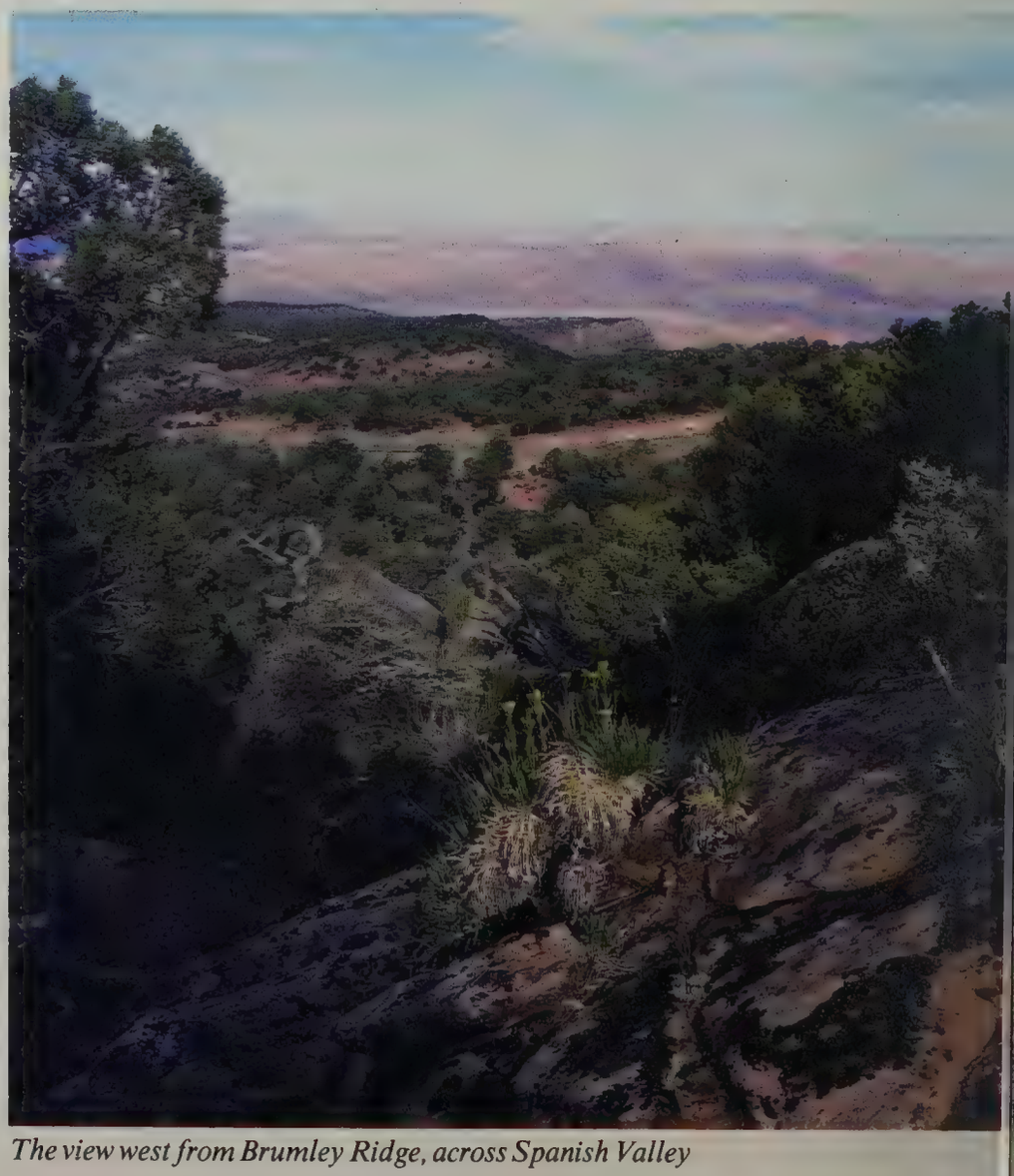


Joe LeMonn

the two have any chemical differences.

The reason for knowing the exact status of the spineless hedgehog cactus revolves around the Endangered Species Act of 1973. In that year, Congress authorized the U.S. Fish and Wildlife Service to begin listing plants, as well as animals, that were on the verge of extinction. To date 200 plants in the United States and its possessions, including many cactuses have made the list. Prized by plant growers, some cactus species have been reduced to near extinction by poaching.

For a plant, being on the list means tha



The view west from Brumley Ridge, across Spanish Valley

Brumley Ridge

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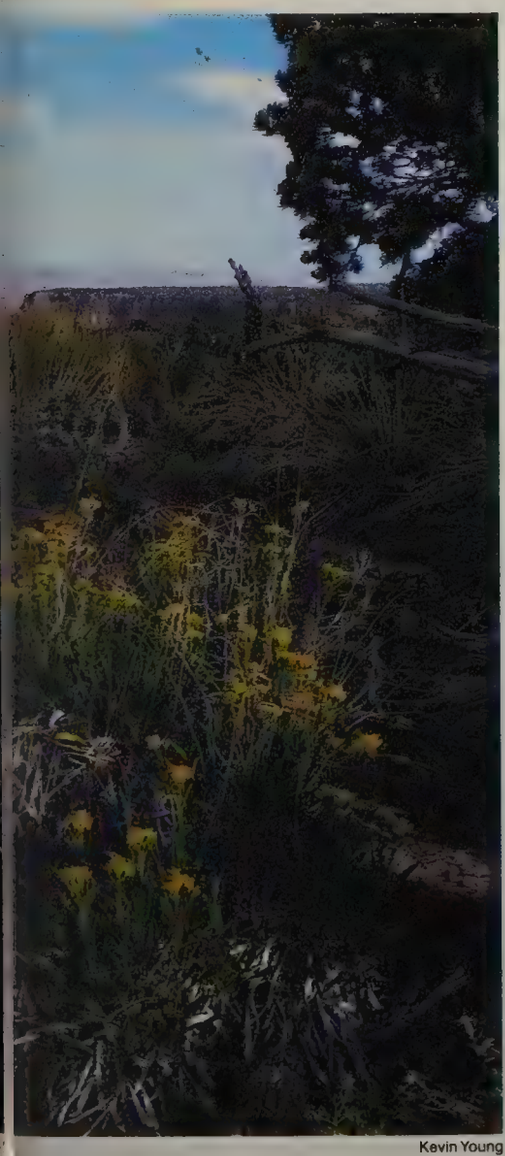
it is to be protected wherever it is found on federal lands. In addition, a listed species may not be transported across state lines. To be protected, however, a plant must be a recognized species, subspecies, or variety. If a plant is only an ecological form, it has no recognition under the law. The continued existence of the spineless hedgehog cactus may well depend on the ability of botanists to quickly and accurately determine its taxonomic status.

"This Land" highlights the biological phenomena of the 154 U. S. national forests. Robert H. Mohlenbrock is Distinguished Professor of Botany at Southern Illinois University at Carbondale.



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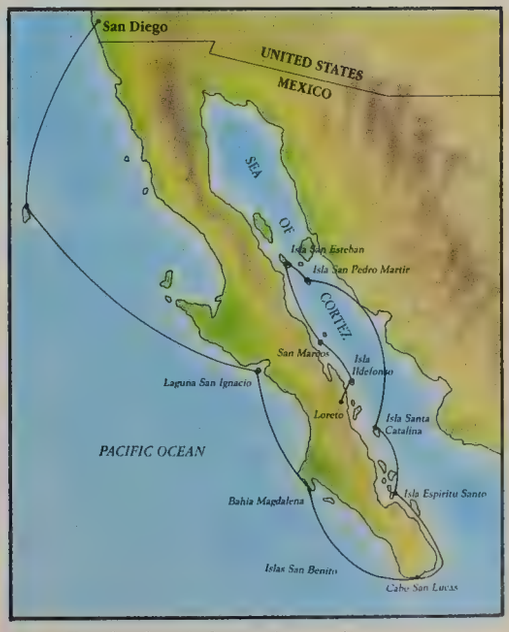

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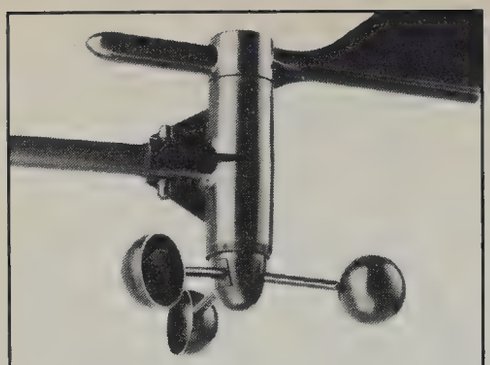

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Outer Planets

by Thomas D. Nicholson

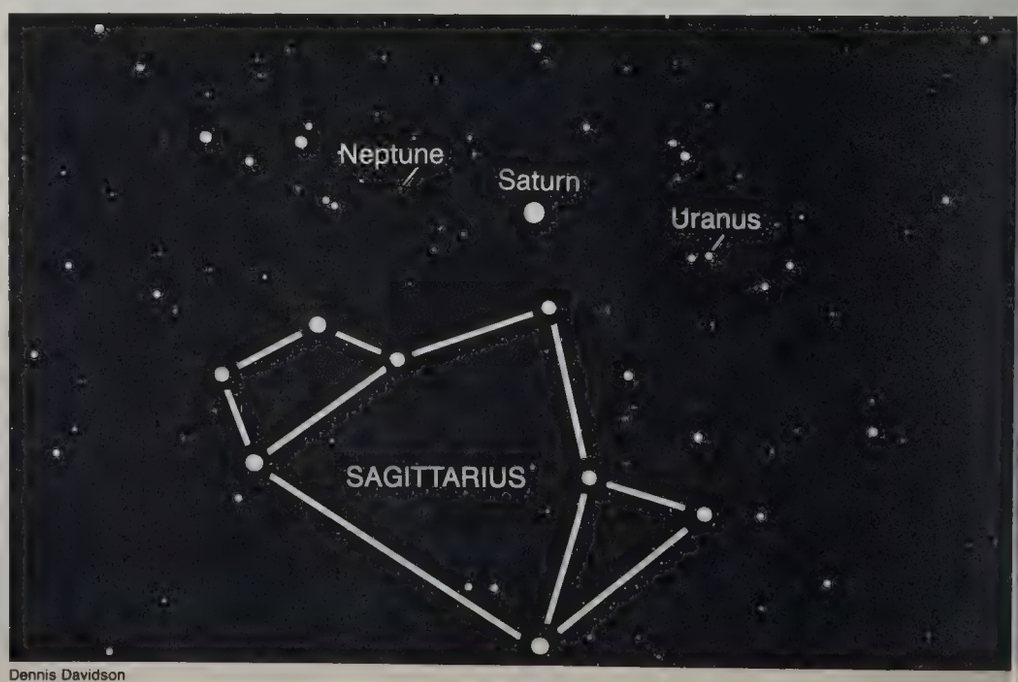
Three outer planets are congregated just above the constellation Sagittarius this month, and they will continue to linger there for the rest of the year. The most distant planet known to ancient astronomers, bright Saturn will help locate the other two planets. Uranus, the first planet to be discovered with the telescope, by William Herschel in 1781, is to the right of Saturn. The more distant Neptune, first recognized by Johann Gottfried Galle in 1846 and visited by *Voyager 2* last month, is to Saturn's left.

Saturn, with a magnitude of 0.4, is easily visible with the unaided eye, which, under good conditions, can see objects with a magnitude of 5 or 6 (the higher the magnitude, the fainter the object). Uranus, however, will require the aid of binoculars to locate, as it has a magnitude of about 5.7. Herschel discovered the planet during the course of a meticulous sky survey with a six-inch telescope of his own design. Herschel was knighted after his discovery, which he initially thought was a comet, was found to be a planet.

A perturbation in the orbit of Uranus eventually led two scientists to independently predict the existence of a more distant body whose gravitational pull affected the motion of the planet. John Couch Adams, while a student at Cambridge in 1843, was the first to calculate the position and mass of Neptune, but his findings were ignored. Later that year the French astronomer Urbain Leverrier repeated the calculations and reported the new planet's position to Johann Galle in Germany. The same day that he received Leverrier's letter, Galle spotted Neptune less than one degree from the predicted location. At a magnitude of about 8, Neptune is just visible with binoculars.

Despite all that has been learned about the outer planets from the *Voyager 2* missions, few people ever see all of them. Take this opportunity to find Saturn, and then Uranus and Neptune with the aid of binoculars. The illustration locates them in the southern sky, clustered above the easily recognizable stars of Sagittarius.

The most distant of the outer planets



Dennis Davidson

Pluto is considerably fainter than Neptune (about magnitude 14) and requires a ten-inch-diameter telescope to see. Currently at the Virgo-Libra boundary, this remote, icy world will reach perihelion (the point in its orbit closest to the sun) on September 5; this occurs only once in its 248-year orbital period. Because of Pluto's highly lopsided orbit, it is now closer to the sun than Neptune, the situation in the period from 1979 to 1999. Regrettably, no space probe is scheduled to visit this mysterious world in the foreseeable future.

Events in the calendar below are given in local time unless otherwise indicated.

September 3: Venus is the brilliant object above the young crescent moon at evening twilight. The planet is bright enough to see at dusk, but low in the evening sky. The bright star between the moon and Venus is Virgo's Spica.

September 4: Apogee moon is farthest from the earth.

September 5: Pluto is at perihelion, which occurs only once every two and a half centuries.

September 8–10: The moon passes from Scorpius to Sagittarius on the 8th shortly after reaching first quarter at 5:49 A.M., EDT. Follow the waxing moon nightly past Sagittarius' "teapot" of stars: in front of the spout on the 8th, in the lid on the 9th, and leaving the handle on the 10th. Bright Saturn is above the moon's path (directly above on the 9th), an easy reference to the moon's motion.

September 11–13: Bright moonglow keeps us from seeing the dim stars of Capricornus around the moon.

September 15: Full moon is at 7:51 A.M., EDT, in Pisces, with the stars of Pegasus' Square above it. This is the harvest moon, rising approximately half an hour later each night from the 12th through the 17th.

September 16: Perigee follows yesterday's full moon, adding to the spring tide's strength today and tomorrow.

September 21: Last-quarter moon occurs at 10:10 P.M., EDT.

September 22: The fall season begins in the Northern Hemisphere at 9:20 P.M., EDT, when the sun arrives at the autumnal equinox in Virgo. Before dawn on this date, the moon is directly above brilliant Jupiter.

September 23: The waning crescent moon forms a triangle with Gemini's stars Pollux and Castor in the dawn sky.

September 24: Mercury passes between the sun and the earth (inferior conjunction) and enters the morning sky.

September 26–27: Leo is home to the morning crescent moon. The Lion's bright star Regulus is below the moon on the 26th and above it on the 27th.

September 29: After a long and futile race with the easterly advancing sun, Mars gives up as an evening star when the sun passes it. Conjunction with the sun, which is directly between the earth and Mars today, is at about 3:00 P.M., EDT, as Mars enters the morning sky. New moon is at 5:47 P.M., EDT.

Editor's Note: The Sky Map in the July issue shows the evening stars and constellations for this month and gives the dates and times for use.

The outer planets are above Sagittarius' Teapot in the southern sky. Saturn is the brightest and is easily visible with the naked eye. Use binoculars to look for Uranus. Under the best viewing conditions, Neptune can be located with binoculars but a small telescope will make it easier.

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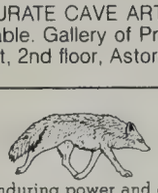

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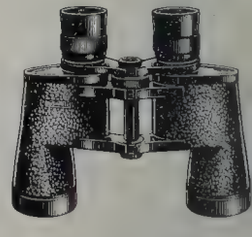

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Extracting Art from Nature

by Joseph Kastner

Albrecht Dürer had a particularly warm place for animals both in his heart and his art. Browse through a collection of the great German master's work and you come upon a siskin perched on the Holy Infant's arm, a hunting dog alarmed at the advance of a predatory beetle, a stork conversing with a saint, and a woodpecker paused in its drumming to glower at a human competitor beating his own drum. Animals populate his large works. Clustered around the Virgin in the *Holy Madonna and a Multitude of Animals* are fox, a couple of owls, a lizard, songbird and some swans. In *The Fall of Man*, the awful moment when Eve reaches ou to the snake for the apple, an unconcerne cat is about to pounce on a transfixe mouse.

The Large Piece of Turf, *a watercolor by Dürer*

Graphische Sammlung Albertina, Vienna

This aspect of Dürer's art is taken up b Fritz Koreny in *Albrecht Dürer and th Animal and Plant Studies of the Renais sance*, based on a 1985 exhibit at th Albertina Museum in Vienna. A weightil researched and elegantly produced bool it encompasses other important artists o the period and a host of minor painter whose copies, imitations, and blatant for eries of Dürer are a major part of Koreny discussion.

In 1494, only twenty-three but alread famous as an engraver, Dürer traveled t Italy, where he was beguiled by th warmth of the climate ("How I sha freeze after this sun," he wrote a frien back home in Nuremberg) and deeply in pressed by the Italian artists who had i troduced a new, realistic approach to n ture in their painting. Dürer eager seized on this approach, as did Leonard da Vinci. Where Leonardo dissected an mals to see how their bodies worked, Dü rer simply showed them as they wer "Life in nature," he wrote, "manifests th truth of these things; therefore observe diligently and do not depart from natu arbitrarily."

He followed this precept in his mo popular painting, *The Hare*, which is als the one most admired by critics and hi torians. In discussing it, Koreny refers the "masterly, unsurpassable sureness

ALBRECHT DÜRER AND THE ANIMAL AN PLANT STUDIES OF THE RENAISSANCE, b Fritz Koreny. *New York Graphic Societ Little, Brown and Company, $75.00; 27 pp., illus.*

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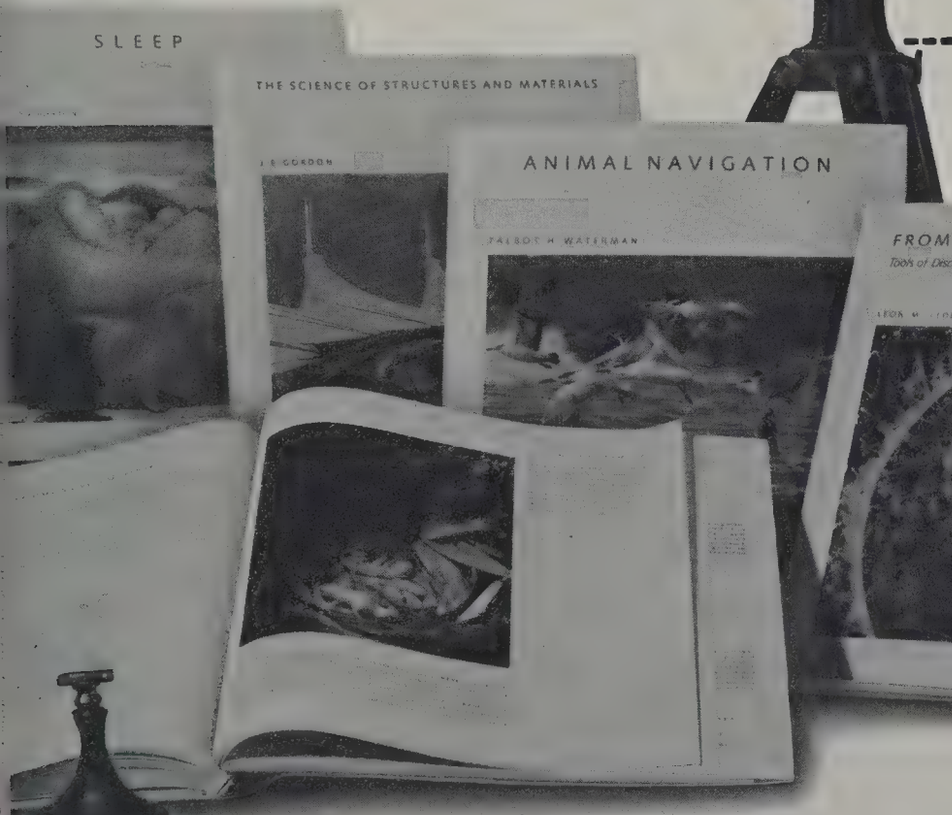

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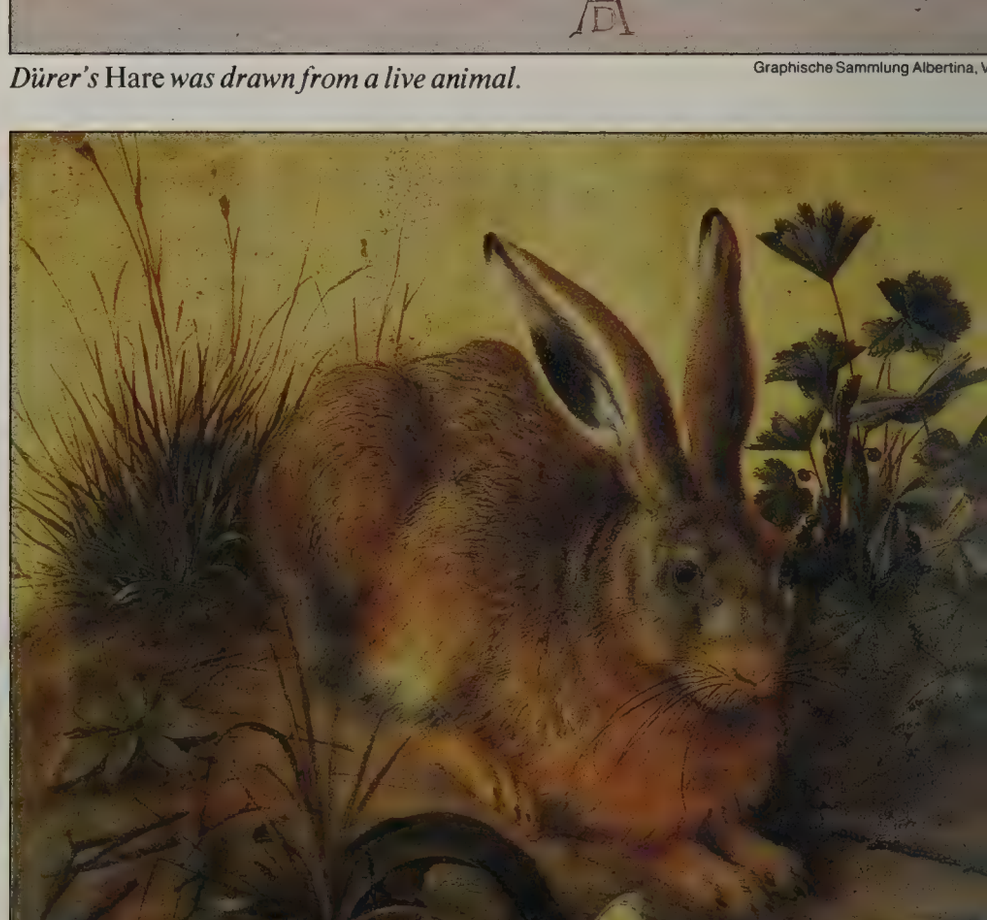

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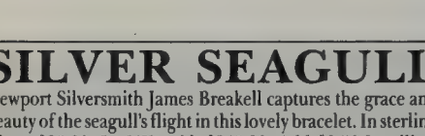

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Dürer's Lion, *above, painted in 1521, was copied by Hans Hoffmann more than fifty years later, right, and signed with his own monogram.*

Germanisches Nationalmuseum, Nuremburg

the brushwork that appears to register each separate hair precisely." But close inspection, he goes on, reveals fluent, broad brush strokes, over which detailed, fine brushwork is laid. On top of that, "color gradations and brush strokes of different qualities evoke the illusion of thick soft fur and throbbing life."

The simplest of subjects in the most expectable of attitudes, *The Hare* is, as one critic called it, one of those "works about which there is really not much to be said, unless one makes a fundamental statement. One must decidedly reject it or acknowledge it unreservedly as a work of genius."

Just as plain and homely are the subject and the title of another famous Dürer nature study, *The Large Piece of Turf*, which depicts a patch of northern European meadow. In it are meadow grass, broad-bladed cocksfoot, dandelion, plantain, speedwell, daisy, yarrow—plants found at the edge of any field on a May morning. Yet this unpretentious scene becomes a landscape in itself. Critics lavish superlatives on it. "A remarkable effort of mastering an infinity of small forms," one critic has said. "A fusion of nature and fantasy into an ultimate artistic reality," says Koreny. And Edwin Panofsky, Dürer's definitive biographer, remarks that "every hair on the fur of the little hare and every grass and herb in a piece of turf are studied and rendered with a devotion closely akin to religious worship."

In scale, these are modest paintin when set against Dürer's grander works. highly successful artist, he was portrait to Europe's wealthiest men, served court painter to the emperor, and creat some of the great altarpieces of the R naissance. An ardent humanist, friend Erasmus and follower of Luther, he w generous, conscientious, convivial, har some—and an enormously efficient

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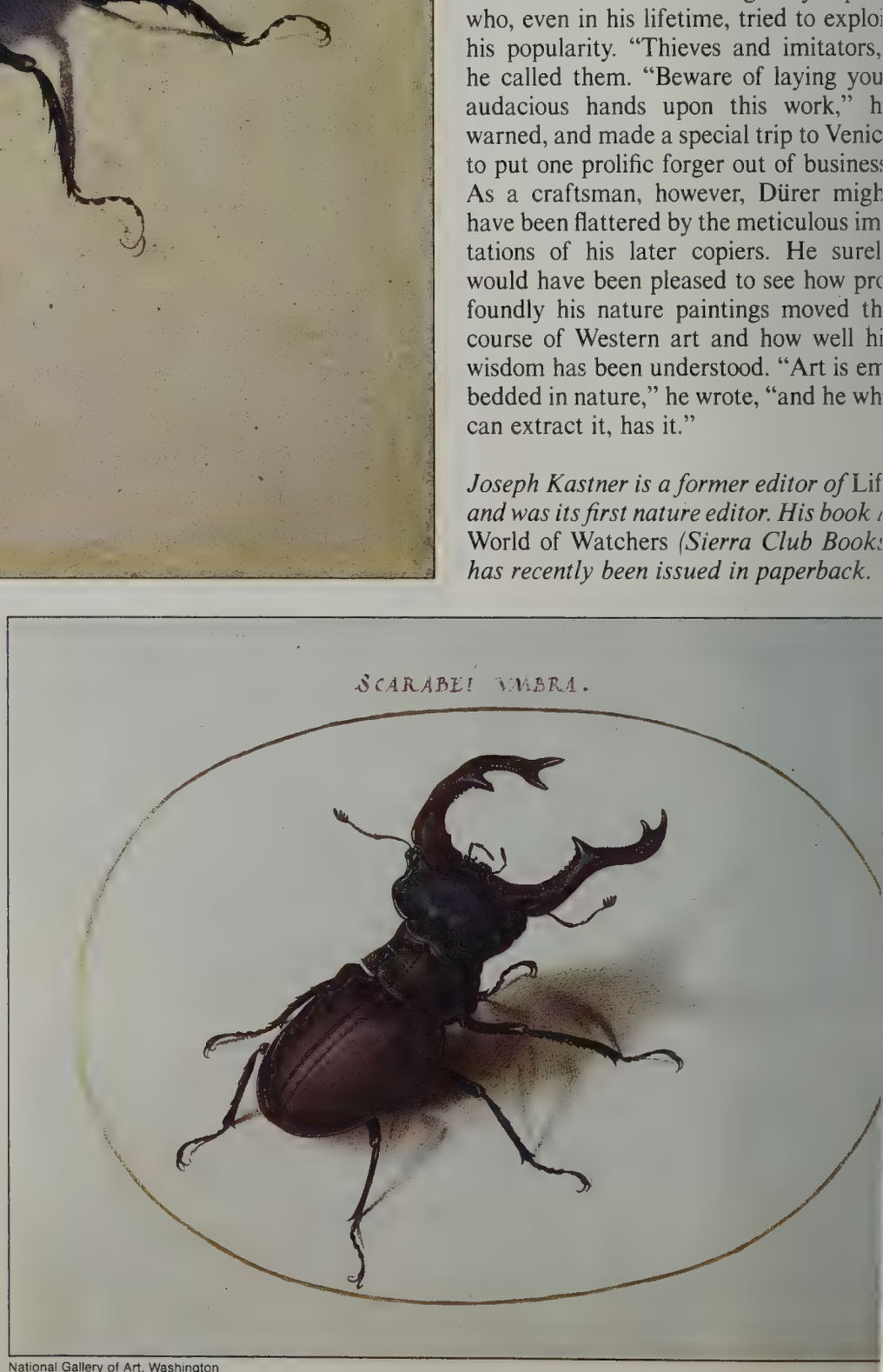
The J. Paul Getty Museum, California

Artist Georg Hoefnagel's male stag beetle, right, is a faithfully executed copy of the minutely accurate portrait by Albrecht Dürer, above.



National Gallery of Art, Washington

nius. Although burdened with a shrewish wife, an overly pious mother, and difficult patrons, he finished scores of major paintings and hundreds of superb engravings. A wide-ranging curiosity drove him to study, with equal interest, mathematics and mythology and the relation of geometry's rules to drawings of the human form. It was, in a way, a fatal curiosity. In 1521 he traveled up into the swamps of Zeeland to examine a huge beached whale. There he contracted malaria and, after years of illness, died in 1525.

He left no school of followers, but in the decades after his death, during what was called the Dürer renaissance, a whole industry grew up occupied with copying his work. Many of the copies were crude forgeries, but a surprising number were skillful re-creations, sometimes strictly faithful to the original, sometimes open variations on them. Koreny gives painstaking attention to questions of authenticity and dismisses, as copies, many works long attributed to Dürer.

The most notable of the copiers was Hans Hoffmann. An estimable artist in his own right and, like Dürer, a court painter to the emperor, Hoffmann lives today largely through his Dürer imitations and re-creations, which are, in themselves, substantial works. Hoffmann was seemingly obsessed with Dürer. He made at least six versions of *The Hare* and several copies of Dürer's magnificent bird detail, the blue roller's wing, sometimes signing them with Dürer's big AD monogram.

Dürer himself was outraged by copiers who, even in his lifetime, tried to exploit his popularity. "Thieves and imitators," he called them. "Beware of laying your audacious hands upon this work," he warned, and made a special trip to Venice to put one prolific forger out of business. As a craftsman, however, Dürer might have been flattered by the meticulous imitations of his later copiers. He surely would have been pleased to see how profoundly his nature paintings moved the course of Western art and how well his wisdom has been understood. "Art is embedded in nature," he wrote, "and he who can extract it, has it."

Joseph Kastner is a former editor of Life *and was its first nature editor. His book* A World of Watchers *(Sierra Club Books) has recently been issued in paperback.*

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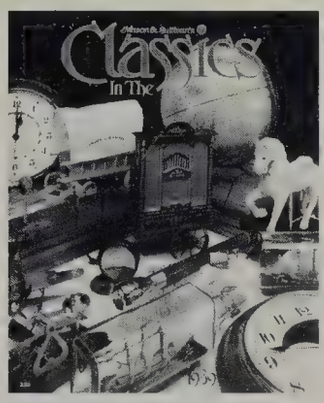

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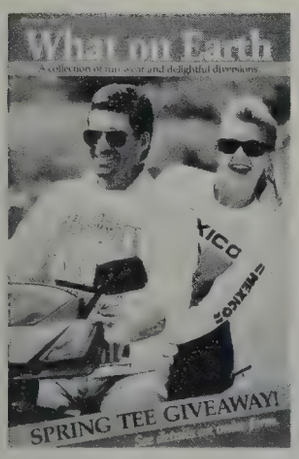

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Insects, Worms, and Other Tidbits

The Mexican diet, before Cortés, obtained high-quality protein from lowly sources

by Raymond Sokolov

After 1492 Europe began to enrich its diet with foods, and eventually with food ideas, from the New World. The most important of these loan-foods are two American Solanaceae, the potato and the tomato. Both originated in the Andes; the tomato had already migrated to Mexico and been cultivated by the time Cortés set foot in what he called New Spain.

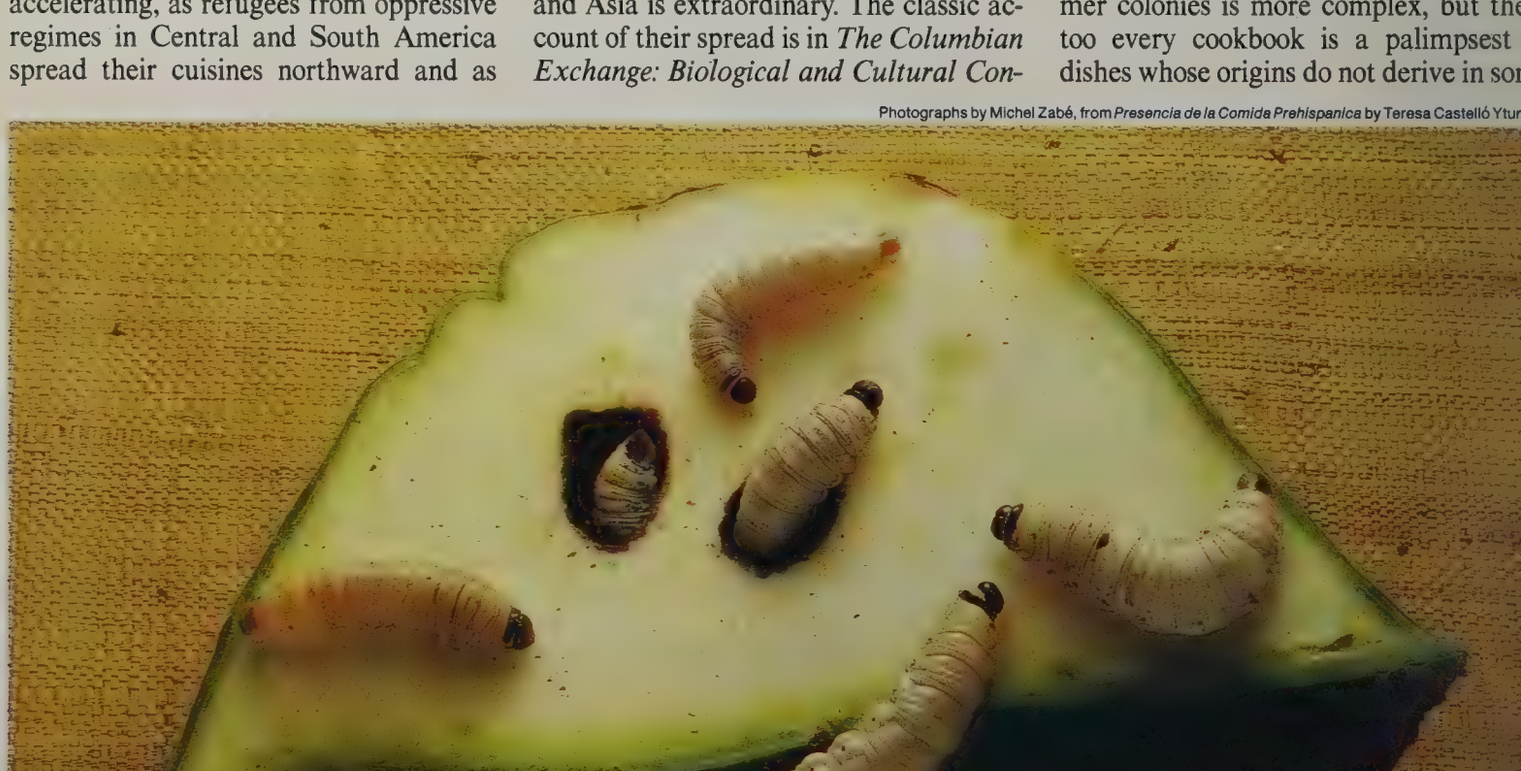
Other major food contributions by the New World to the Old included chocolate, vanilla, and all the multifarious *Capsicum* peppers, from hot chilies (frequently known by their other major pre-Columbian name, *aji*) to the mildest bell peppers. A complete list of New World loan-foods can never be compiled since the process continues today and may even be accelerating, as refugees from oppressive regimes in Central and South America spread their cuisines northward and as adventurous palates in the United States and elsewhere create a secondary "gourmet" market for previously unfamiliar foods. The pickled jalapeño pepper is now a supermarket item in New York, not a specialty food. Fresh jalapeños are as available, seasonally, on the Upper West Side of Manhattan as fresh favas (a naturalized form of European broad bean).

Other New World foods that have established themselves in the Old World include corn, pumpkin and other squashes, beans (including kidney beans, limas, green beans, butter beans), sweet potatoes, manioc (cassava, tapioca), peanuts, papaya, guava, avocado, and pineapple. The nutritional and culinary importance of these plants in Europe, Africa, and Asia is extraordinary. The classic account of their spread is in *The Columbian Exchange: Biological and Cultural Consequences of 1492,* by Alfred W. Cros Jr. (Greenwood Press, 1972).

As Crosby shows (building on the S viet botanist N. I. Vavilov's *Origin, Var tion, Immunity and Breeding of Cu vated Plants*), what people from Beijing Djibouti now eat is almost never a tra tional cuisine going back centuries. "A thentic" culinary practice virtually eve where is not the immobile tradition th traditionalists wish it to be. Since 149 everybody's larder and recipe file ha changed radically. The sweet potato, t peanut, and the chili pepper turned t nutrition of China upside down. Afri lives on American transplants: manio corn, peanuts, pumpkins.

The story for Europe and Europe's f mer colonies is more complex, but the too every cookbook is a palimpsest dishes whose origins do not derive in so

Photographs by Michel Zabé, from *Presencia de la Comida Prehispanica* by Teresa Castelló Ytur



*Butterfly larvae (*gusanos de maguey*) tunnel through the leaf fiber of a maguey plant.*

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simple way from age-old peasant practices or the elegant menus of royal courts. But to analyze these palimpsests properly and to determine which of the "traditional" foods we eat are pre-1492 and which were imported afterward, we have to establish the specific qualities of the pre-Columbian cuisines in each culture that interests us. Mexico is the best place to begin because the historical record is rich and because the pre-Hispanic foods and foodways have survived virtually intact through the centuries, even while Mexican cooking absorbed as much of Europe as possible.

When Cortés conquered Mexico in short order after landing in 1519, he bit off more than he or the Spanish Empire could conveniently chew. Mexico was no Caribbean island with Stone Age Arawaks or Tainos spearing fish for survival. Mexico was a major world civilization with a vigorous culture that continues to challenge imported European culture today. Even after smallpox and other European diseases wiped out vast numbers of people, those hordes that had been baptized and preached to in the outdoor chapels that now grace outlying ghost towns all over Mexico—even after these indigenous innocents had perished, there were still more than enough native Mexicans to carry on local food traditions in tandem with the new ideas and foods from Spain and the Spanish Empire.

Tequila is a well-known case in point. It is a distillation of the fermented sap of the agave called maguey. Only the distillation, and its commercial systematization in the state of Jalisco, owe anything to Europe. The plant itself (*Agave salmiana* and other species) was at the heart of pre-Hispanic cooking. Its sap was and is tapped from its heart and drunk fresh as *aguamiel,* or "honey water." When *aguamiel* is fermented, which it was long before Cortés, the result is pulque, a perishable, low-alcohol, milky beverage that still commands the loyalty of local connoisseurs. Tequila is distilled pulque, a Hispanicized cognac, as it were, made from the indigenous agave wine.

Some people cook with pulque; others eat the maguey's flowers. But the most dramatic pre-Hispanic culinary contri tion of the maguey to modern Mexi gastronomic life is entomological. I talking about the butterfly larvae that fest the plant's thick, pointed leaves its roots. The Franciscan friar Bernard de Sahagún mentioned both:

> There are some worms they call *meoc* which means maguey worms. They are white and they grow in the magueys, t cut a hole and go inside, eating and send out their excrement through the hole which they entered. They are very good eat.

These larvae are also known *palomillas del maguey* (maguey squa *champolocos, meocuilines,* and *pecahs* scientifically, *Aegiale hesperiaris.* butterfly that produces them flut about between June and October, lay its eggs under the fleshy leaves of pulque maguey (*Agave salmiana* and *mapisaga*). Modern science rati Sahagún's account of the ravenous life the maguey worm in the heart of the pla

Larvae harvesters (I paraphrase the count in Teresa Castello Yturbide's m

Insects, along with their eggs, larvae, and pupae, are toasted or ground up in tamales.

ficent and sometimes terrifying *Presen-
a de la Comida Prehispanica,* Banamex,
986) poke about among the maguey's
wer leaves, looking for the telltale tun-
ls at the base of the leaves near the outer
lges. Working very carefully with a ma-
ete, so as not to disembowel the larvae
nwittingly, they cut open the leaf. To
tract the larvae whole, they use hooks
rmed by cutting thin strips from the
lge of a maguey leaf. Then they remove
l its spines except for one at the end of
e strip. This they form into the hook
ey use to catch the larvae by the head.
o store the larvae, they make pouches
ith the skin of a tender new maguey leaf,
hich is called *mixiote* (it gives its name,
necdochically, to a dish made of chunks
marinated meat wrapped in *mixiote*
ouches and steamed).

To cook the larvae, people sometimes
st put a whole *gusano* (larvae)-filled
ixiote over coals or hot ashes, or they
ight just put the larvae directly on a
akestone until they swell and stiffen,
rning golden brown and crunchy. And
is is not some quaint account of a long-
rgotten practice. Castello Yturbide non-
alantly mentions that maguey larvae
an be obtained in April in the market of
an Juan in Mexico City or in Actopan
nd Ixmiquilpan (two villages of the state
Hidalgo) or in farm hamlets around
lexico City.

Gusanos de maguey are only one of a
ng list of surviving pre-Hispanic odd-
ents, mostly what we would call vermin,
at Castello Yturbide catalogs and
esents to us in Michel Zabé's eerily ele-
ant photographs. Most basic, I suppose,
e various algae and pond scum, such as
aculito del agua (*Phormidium tenue,
hroococcus turgidus*), gathered in bas-
ts and mixed with the herb *epazote,*
ied chilies, and salt; the resultant
dough" (*masa*) is then spread over a corn
af, steamed like a tamale, and eaten by
self or in stews. Castello Yturbide says
e bought these tamales from vendors of
sh tamales in the capital district at Xo-
himilco and Texcoco.

The story of another edible alga,
pirulina, is even more exotic, even in-
piring. In 1582, Juan Bautista Pomar de-
ribed "a kind of food they call *tecuitlatl*
ade into cakes from pond slime, dark
een in color and called cheese of the
rth by the Spaniards." *Tecuitlatl* flour-
hed in abundance in Lake Texcoco in the
alley of Mexico, but then it seems to
ave vanished. However, following up on
suggestion by a Belgian botanist in 1964,
lexican scientists, drawing on research
one in the biologically similar waters of
ake Chad in central Africa, were able to

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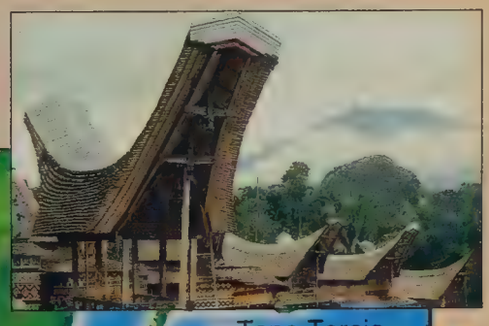

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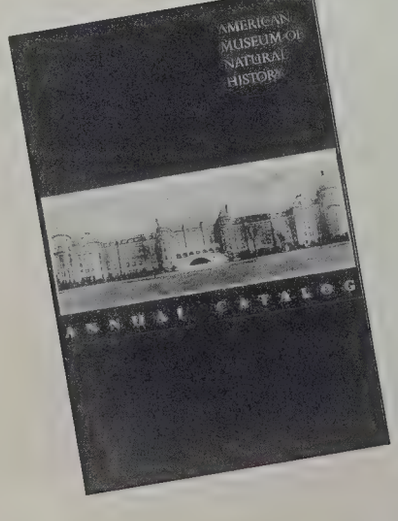


revive the plant and harvest a ton of *espirulina* a day in 1973, thus returning the alga to the diet of Mexicans.

The list of insects eaten in Mexico then and now is awesomely long. It includes water bugs (*moscos de pájaro*), whose eggs are still gathered in the same manner described by Sahagún: bundles of reeds stuck upright in the muck in shallow water attract the *moscos,* which lay eggs on them. After a month of this, people "harvest" the bundles, dry them out, and shake the eggs onto cotton sheets. Sahagún says they were then eaten in tamales and tortillas. Today, according to Castello Yturbide, they are toasted, ground up, and made into little cakes held together with turkey egg. This is a documentable survival of a dish that goes back at least to 1798, when, according to Manuel Orozco y Berra, a scientist of the day, these apparently humble concoctions were a garnish for the festive dish called *revoltijo,* served on Christmas Eve and at the vigil of Thursday night of Holy Week. "The taste," he wrote cryptically, "is like caviar but not so tasty."

Mexicans also continue to eat locusts, available all year at markets in Oaxaca and Atlixco, toasted and eaten with tortillas and a sauce of *chile pasilla;* mountain chinch bugs, eaten toasted or living; oak-boring beetles, popular as snacks among Mixtec peasants; red-ant eggs (actually the pupae and larvae are eaten in a spec *mole* with nopal cactus or in turkey-e bound cakes); and in Jungapeo, Mich cán, they eat wasps.

Some other out-of-the-way vestiges pre-Hispanic cookery include the pri tive salamander called *axolotl* ("good eat," wrote Sahagún), formerly eaten t at a time wrapped in corn leaves, but day allegedly served in broth to frail c dren; frogs and tadpoles; iguanas, sold l in Acapulco and stewed in a tomato-c broth thickened with corn flour; rat snakes, served with hot sauce in Chih hua and added to the still (for good luc during the preparation of the country gut called *sotole;* caimans; monke roasted like suckling pigs in Chiap opossums; armadillos; and rodents too merous to mention.

All this weird but protein-rich food s plemented a diet based on corn and sh on dependable meat from livestock. by the time the Spaniards came and proved the situation with their pigs a sheep, the taste for certain toasted vern had lodged itself firmly in the Mexic appetite—where it remains today, a liv symbol of the persistence of the countr pre-Hispanic roots.

Raymond Sokolov is a writer whose s cial interests are the history and prepa tion of food.

Atole de Platano
(Plantain Gruel)

(From *Platillos Regionales de la República Mexicana,* by Josefina Velazquez de Leon, Editorial Diana, 1987)

- 10 ripe (yellow) plantains
- 2 quarts milk
- 1 pound sugar
- 1 piece cinnamon bark
- 2 tablespoons honey
- 6 tablespoons corn flour (the variety sold in Hispanic markets as *masa harina*), dissolved in a little milk

1. Peel and trim the plantains. Chop fine in a processor. If necessary, add a little milk to speed the chopping.
2. In a large, heavy saucepan, combine the milk, sugar, and cinnamon. When the mixture begins to boil, stir in the plantain and honey. Let it cook over low heat until it thickens. Push through a strainer and mix in the corn flour mixture. Return to heat and continue cooking, stirring constantly, until it reaches the consistency of a loose porridge.

Yield: 8 to 10 servings

Arnulfo Luengas Rosales's Avocado with Shrimp and Cilantro

(From *El Universo de la Cocina Mexicana,* Banamex, 1988)

- 4 avocados
- 1 bunch fresh coriander leaves
- 1 cup heavy cream
- 1 package gelatin
- 1 pound cooked shrimp, peeled and cleaned
- Olive oil

1. Peel and pit the avocados. Purée in a blender with the coriander leaves.
2. Beat the cream until it thickens. Then fold it into the avocado mixture.
3. Dissolve the gelatin in a half cup o cold water. Then fold it into the purée
4. Spread the purée in a small ring mold Arrange the shrimp evenly around the ring. Spread purée over them to make a smooth surface. Then paint with ol ive oil to prevent discoloring.
5. Chill overnight or for several hours, so that the mousse solidifies.
6. Before unmolding, pass the mold through lukewarm water. Invert and unmold on a serving platter. Paint the surface with olive oil and serve.

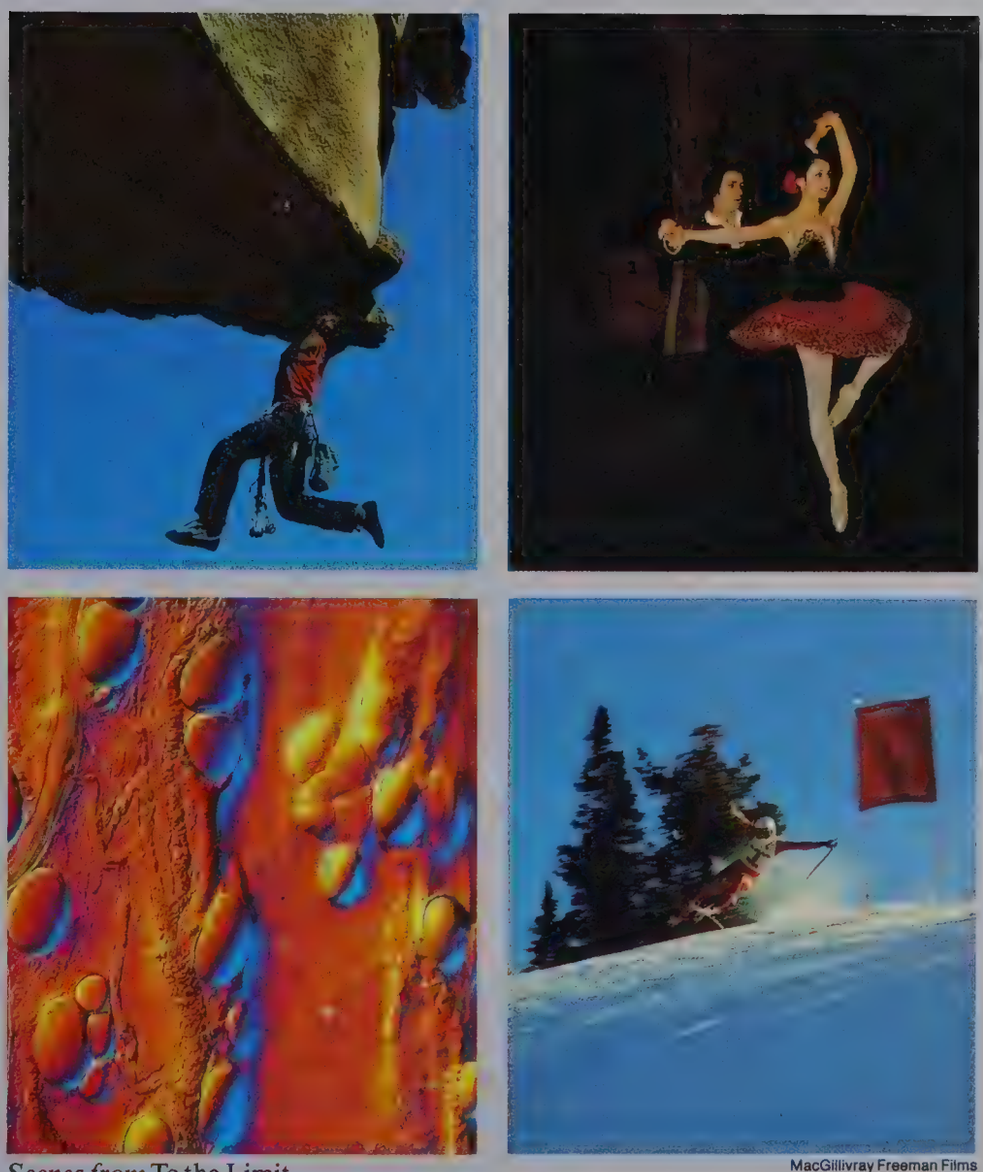
Yield: 8 servings

At the American Museum

To the Limit

To the Limit, a new giant-screen film now playing in the Naturemax Theater, explores what happens to the human body during activities requiring physical strength, stamina, and skill. Directed by Greg MacGillivray and narrated by Richard Kiley, the film takes viewers to the top of Yosemite's El Capitan, down an Aspen ski slope, and onstage at Moscow's Bolshoi Ballet, as well as inside the body for a close-up look at the respiratory, circulatory, and nervous systems in action. Scenes of spectacular feats, such as rock climbing, are interspersed with images of the body's internal reactions under stress.

In the Naturemax format, 70-mm film is turned on its side to create an image ten times the size of a standard 35-mm frame. The four-story image is then projected onto New York City's largest movie screen. *To the Limit* is the first film to use a number of specially developed new technologies. Endoscopic and microscopic lenses enable the camera to show the inside of the heart and lungs from the point of view of a blood cell. A special high-speed camera capable of shooting one hundred giant frames per second was built to capture images of sprinter Carl Lewis and ballerina Nina Ananiashvili in slow motion. For show times and ticket prices, call (212) 769-5650.



Scenes from To the Limit

MacGillivray Freeman Films

Fall Workshops

The Museum's Education Department presents a series of participatory workshops this September and October in music, dance, arts, and crafts. Adult workshops include Andean wind instruments, the *shekere* (a musical instrument made from a calabash), mambo, tie-dye, and African batik. Adults and teen-agers can learn the arts of African basketry, Chinese paper cutting, Japanese kite making, and *arnis,* the Philippine art of stick fighting. Workshops for children aged eight to thirteen feature Caribbean storytelling and writing, Sudanese Nuba face painting, and making musical instruments out of ordinary household items. Fees range from $10 to $30, and enrollment is limited. For information and registration, call (212) 769-5315.

Tibetan Ritual Dances

The ancient monastic dances of Tibet represent the movements of Vajrayana Buddhism's celestial beings, as seen in the visions of Tantric practitioners. A dozen Tibetan monks from the Namgyal Monastery will present a selection of these dances at the Museum in a special program, "Dances from the Diamond Realm." Wearing elaborate masks, the monks will perform the Dance of the Cemetery Lords, traditionally danced at year-end to purify the year's accumulated negative forces. The monks will also present the Deer Dance, in which a deer makes offerings to Dharmaraja, the king of dharma; and an excerpt from the Five Dakini (female deity) Dance. Other dances tell stories; among them are the Dance of the Old Man, a tale of Mongolian origin about an old man who hunts a tiger, and the Black Hat Dance, a reenactment of the ninth-century assassination of King Langdarma, who nearly eradicated Buddhism in Tibet. The program will be given in the Kaufmann Theater for three performances only, on Friday, September 8, at 7:00 P.M., and on Saturday, September 9, at 2:00 and 6:00 P.M. Tickets are $15 for members and $18 for nonmembers and may be ordered by mail; seating is limited. For more information, call (212) 769-5173.

These events take place at the American Museum of Natural History, located on Central Park West at 79th Street in New York City. For more information about the Museum, call (212) 769-5100.

A Wing for the Birds

The American Museum of Natural History's Whitney Wing, a block-long, eight-story edifice along Central Park West, celebrates its fiftieth anniversary this year. The building, with its public galleries, extensive research laboratories, and vast storage space for its world-renowned bird collections, owes its existence primarily to the sustained generosity of the Whitney family and the adroit maneuvers of a Yale football team physician.

Dr. Leonard C. Sanford did much more than minister to Yale University's players. He was an accomplished surgeon, a professor in the university's Medical School, and an ardent collector of birds, particularly exotic species from distant places. Sanford also was a dedicated supporter of the American Museum's Ornithology Department and a Museum trustee for the final three decades of his life.

With his own money and, more often, with money from friends, Sanford supported expeditions to study and collect birds in remote parts of the world. He persuaded a Museum trustee, Frederick F. Brewster, who also lived in New Haven, Connecticut, to finance the Brewster-Sanford Expedition (1912–17) around South America. The fieldwork produced a large collection of Southern Hemisphere sea and land birds and culminated in the production of numerous scientific reports, as well as Robert Cushman Murphy's *Oceanic Birds of South America,* an unsurpassed classic on seabirds.

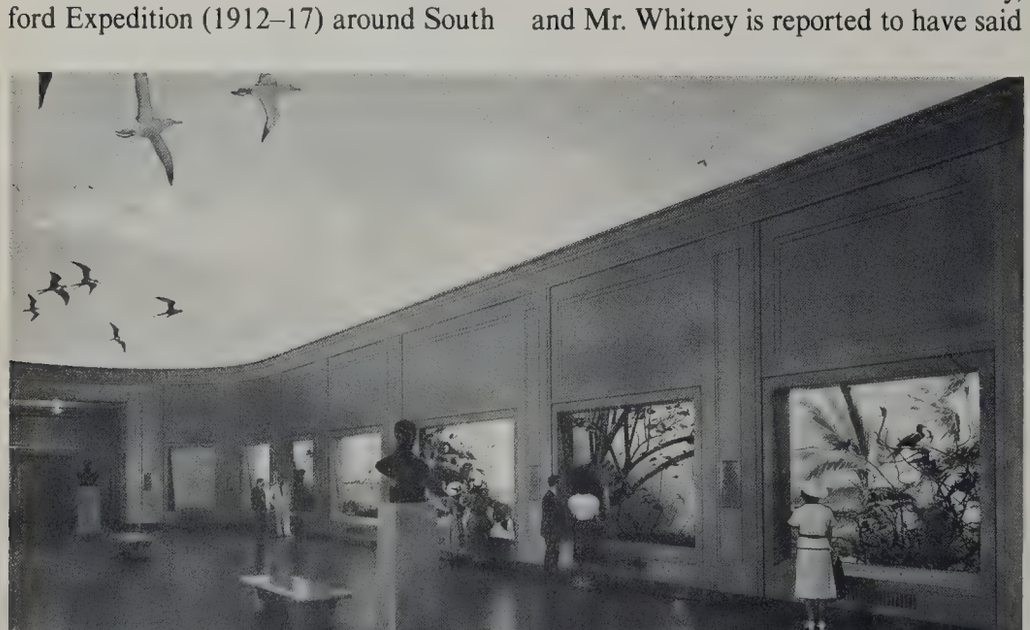
The success of the South American expedition encouraged Sanford to consider a much more ambitious—and expensive—dream: a series of bird-collecting voyages throughout the South Pacific. He saw in the Pacific, a huge body of water dotted by thousands of islands difficult of access and scarcely known ornithologically, one of the last large expanses of the globe that would repay its exploration with new birds and expanded knowledge. But then World War I intervened.

After the war, the idea of a Pacific expedition was resurrected. In the words of Murphy, "No one to this day knows by exactly what steps Dr. Sanford lured his friend Harry Payne Whitney to take on such an expensive and prolonged undertaking. The original agreement was, I believe, limited to four years, but at the end of that period, the seductive tongue of Dr. Sanford continued to work effectively, and Mr. Whitney is reported to have said on one occasion to his friend 'Heff' Sa 'Len's got me hogtied.' It is likely, course, that Mr. Whitney was persona interested to a greater degree than freely acknowledged." Whitney con ued to support the Whitney South S Expedition for twelve years.

Beginning in 1920, under the leaders of Rollo Beck for some seven and a h years and, thereafter, of Hannibal Ham and William Coultas, the expedition ited more than a thousand islands sc tered through Micronesia, Polynesia, a Melanesia. As the large collections beg arriving back in New York, space had be found for them. Sanford again proached Whitney. In Murphy's wor "It is not recorded when he first broach this idea to Mr. Harry Payne Whitney. 1929, however, the suggestion had acco plished its deadly purpose. In the spring that year after estimates on the cost o new Museum wing had been obtain Mr. Whitney offered to put up one-half the necessary funds, if the City of N York would provide the rest. For once our long history of municipal relations, city accepted with alacrity—no dou with full realization of the fact that would otherwise ultimately have to m the entire cost of such a building. Fur were made available just before the l summer financial collapse of 1929 a early in 1931, ground was broken and c struction commenced."

Whitney died in 1930, but his wid Mrs. Gertrude Vanderbilt Whitney, Cornelius Vanderbilt Whitney, a daughter, Barbara Whitney Peck, p sued the task with enthusiasm. Mrs. Wh ney decided that the principal exhi floor of the new wing, now the Whitn Hall of Oceanic Birds, should be a mer rial to her husband and her father-in-l William C. Whitney. The elder Whitn had, a generation before, provided fu for the collection of fossil horses in west North America.

The Whitney Memorial Hall was signed with eighteen habitat groups rep senting a range of Pacific island typ from the sun-drenched tiny atolls ris barely a few feet above the ocean surf to the high, steep, and cloudy peaks



Photographs from AMNH

Visitors in the newly opened Whitney Memorial Hall in 1953

rge volcanic islands; from frigid subarc- c Little Diomede to wind-swept sub- ntarctic Snares Islands. Bird artist Fran- s Lee Jacques painted all of the ckgrounds, at the same time perfecting e technique of realistically reproducing tual Pacific scenes on a curved back- round. Some years ago, when I first saw ouna Falls in Papua New Guinea, I had e overpowering feeling of having been ere before. Only months later did I real- e that it was the accurate background of e habitat group that had been in the ck of my mind at the time.

The Whitney South Sea Expedition col- cted many of the specimens on exhibit. ut the detailed studies of the actual lo- alities reproduced within the Museum ses were carried out later. To obtain the notographs and accessories needed, Mu- um staff sailed as guests on private chts to Pacific islands designated for clusion in the Whitney Hall. Three ma- r expeditions, which completed studies r eleven of the eighteen habitat groups, ere the Templeton Crocker Expeditions 1934 and 1936 on the yacht *Zaca,* and e Fahnestock Expedition of 1940 on the hooner *Director II,* belonging to Sheri- n and Bruce Fahnestock. The last expe- tion was shipwrecked on the Great Bar- er Reef of Australia, but no one was hurt d the collections, extensive notes, and notographs were saved.

With several exhibits completed, the hitney Wing was officially dedicated on ne 6, 1939, at a ceremony presided over Museum president F. Trubee Davison d attended by members of the Whitney mily and 400 guests. After the dedica- n, work continued on the Whitney Me- orial Hall. When Mrs. Whitney died in 42, Cornelius Vanderbilt Whitney took the cause, and during his active World ar II service, his sister, Mrs. Barbara hitney Peck, became the family repre- ntative. Postwar collections were made r the final four exhibits, and on January , 1953, the Whitney Memorial Hall of cific Life was formally dedicated.

The first floor of the Whitney Wing ntains the Sanford Hall of the Biology Birds, a memorial to a man who gave e Museum decades of enthusiastic sup- port and his own personal bird collection of tens of thousands of specimens. In Sanford's own words: "There are few individuals who are more ambitious for [the American Museum] than I am. Educationally it is preeminent, and there is nothing in the world that can compare with it."

In 1931, Sanford was approached by Lord Walter Rothschild, of Tring, England, when he decided to sell his vast private collection of birds. Sanford knew that Lord Rothschild's collection of some 280,000 bird skins was rich in rarities and had adequate representation of insular faunas from remote archipelagos and of extraordinary families, such as the birds of paradise. The geographical strengths of the collection dovetailed with the collections held by the Museum. Its acquisition would give the American Museum the greatest bird collection in the world. Sanford and Richard Archbold, whose later expeditions to New Guinea would expand the Rothschild coverage of that area, put up their own funds to hold the Rothschild Collection until Sanford persuaded Mrs. Whitney to purchase the collection for the American Museum.

The Whitney and the Rothschild collections both stressed locality data and series of specimens from any one place. With this information, variation between populations can be distinguished from seasonal, age, or sexual variation within a bird population. Hundreds of scientific papers have since been written using these specimens as a data base, and Ernst Mayr's *Systematics and the Origin of Species,* a landmark in our current understanding of speciation and zoogeography, was a direct outgrowth of his studies of these two great collections.

Today the bird collections in the Whitney Wing remain a magnet for ornithologists from around the world. Its cases house examples of 99 percent of the known species of birds. Staff and visitors use the irreplaceable specimens for a wide variety of research, such as geographical distribution and speciation, comparative DNA studies, anatomical comparisons, and feather-pigment chemistry. Almost all of the field guides that have contributed so much to the popularity of birds would have been impossible without these collections. Scientists continue to find within the Whitney Wing the raw materials with which they can form and test new hypotheses.

Mary LeCroy

Part of the Rothschild collection leaves Tring, England, bound for the American Museum of Natural History in 1932

Serious Necking

Photograph by
Gregory G. Dimijian

As the photographer observed the shy animals on the plains of Kenya from a quarter mile away, they took turns swinging their heads at each other, entwining and rubbing their long necks together for almost an hour. The participants were two males engaged in a graceful form of sparring to establish dominance. Locked together, the giraffes pushed each other, trying to free their necks for another swing. In the 1950s, Anne Innis, a zoologist observing giraffes in the eastern Transvaal of South Africa, witnessed a baby male sparring with two adult bulls, who "hit him gently from both sides, and the baby between them waved his head about in all directions, sometimes missing both of them."

On rare occasions, such "necking" between adult males escalates into serious fighting. A giraffe may use his head, with its two horns, like a club, whipping it back and swinging it at his opponent's body with tremendous force. The combat nonetheless proceeds at a leisurely pace, with long pauses between blows that can be heard across the plains.—*R. A.*

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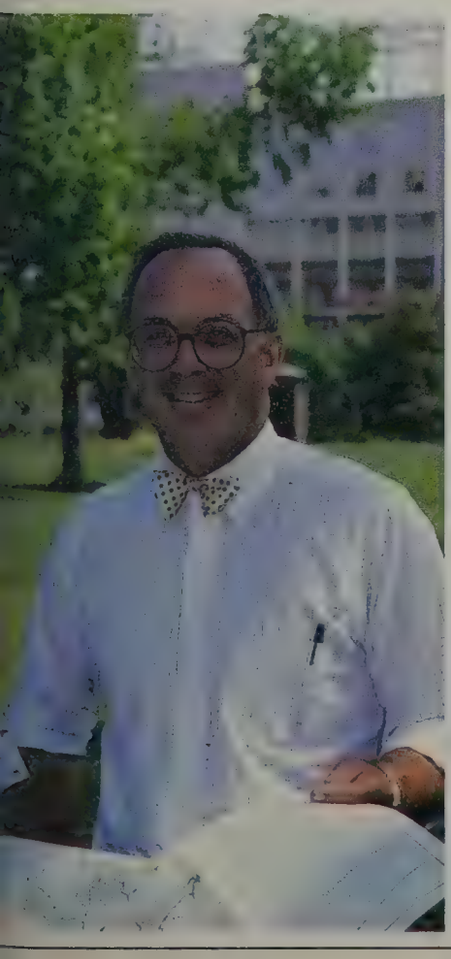
Authors

Jefferson Chapman, Hazel R. Delcourt, and **Paul A. Delcourt** (page 50), all at the University of Tennessee, were among the researchers from many disciplines who documented the human and natural history of the lower valley of the Little Tennessee River, prior to construction of the Tellico Dam. Chapman (right) is curator of archeology at the Frank H. McClung Museum and research associate professor of anthropology. Hazel R. Delcourt (center) and her husband, Paul A. Delcourt (left), are on the faculties of the Department of Geological Sciences and of the Graduate Program in Ecology. They are also codirectors of the Center for the Quaternary Studies of the Southeastern United States. For additional reading, the authors recommend *Tellico Archaeology: 12,000 Years of Native American History,* by Jefferson Chapman (Knoxville: University of Tennessee Press, 1985); *The Southeastern Indians,* by Charles Hudson (Knoxville: University of Tennessee Press, 1976); and *Travels,* by William Bartram (New York: Penguin Books, Inc., 1988).

Robert D. Ohmart (page 34) has spent most thirty years observing the special-ed plants and animals of the American outhwest. Currently a professor of zool-gy at the Center for Environmental udies at Arizona State University in empe, Ohmart also applies his knowl-lge of desert ecology to management oblems of river systems. To observe rd behavior firsthand, he need go no rther than his own backyard, where he joys raising parrots. For more on the e and lore of roadrunners, readers can nsult Hamilton A. Tyler's *Pueblo rds and Myths* (Norman: University Oklahoma Press, 1979). The classic scription of the roadrunner remains at by George Miksch Sutton in Arthur leveland Bent's *Life History of North merican Cuckoos, Goatsuckers, Hum-ingbirds, and Their Allies,* Part 1 New York: Dover Publications, Inc. 964, reprint).



Daphne Gail Fautin (page 42) first became interested in the clownfish as a Peace Corps volunteer during the 1960s; while teaching biology in Malaysia, she had time to go skin diving on the nearby reefs. She found the symbiosis between the clownfish and its anemone home not only intriguing but also easy to study. Because the fish never leave their tiny domain, she could return to a marked anemone in her research area days later and resume observation of the same individuals. Although she has studied life on tropical reefs throughout the Pacific and Indian oceans, she admits that she has never set foot in the Caribbean. Fautin is currently the director of research at the California Academy of Sciences, in San Francisco, as well as associate curator for the Academy's Department of Invertebrate Zoology. She is extending her work on symbioses of marine invertebrates to include animals found on the deep-sea floor. For further reading, Fautin recommends Gerald R. Allen's book *Anemonefishes* (Neptune: TFH Publications, Inc., 1975).

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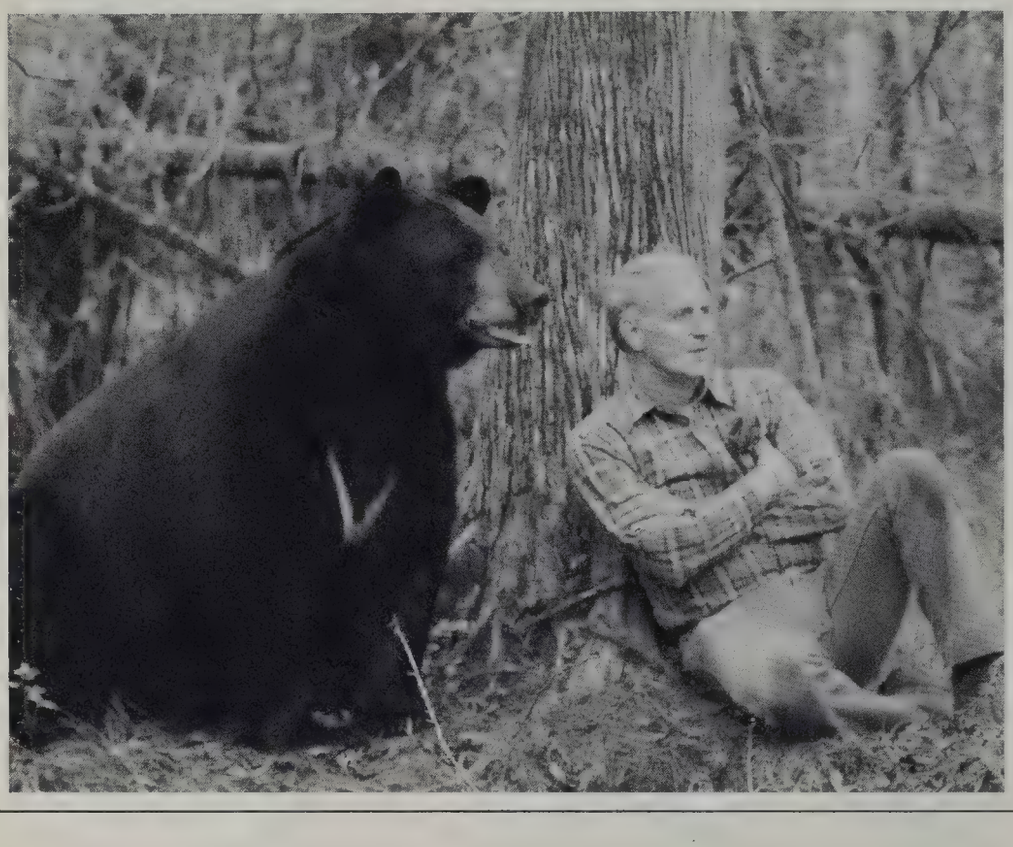

Working with what he calls the J Goodall approach to bear resear **Lynn Rogers** (page 60) and his resea team learn all aspects of an individ bear's life by observing it forty-ei hours at a time. A wildlife research ologist for the North Central Forest periment Station of the U. S. Forest S vice in Ely, Minnesota, Roger's ini contact with bears came with his f wildlife job at the Cusino Wildlife search Center in Michigan. There helped move nuisance bears far fr their home sites and then watched to how many of them returned. Rog earned a masters in ecology and sta tics and a Ph.D. in wildlife ecology fr the University of Minnesota. But he s his real training came in the wo where he observed the bears themsel For additional reading, Rogers sugg a forthcoming book, *The Great Am can Bear,* by Jeff Fair (Minocq NorthWord Press, 1990).

Whenever **Gregory G. Dimijian** (page 92) can take time off from his psychiatric practice in Dallas, he travels to other continents to take photographs, a hobby since he was eight years old. He and his wife, Mary Beth, travel to East Africa so frequently that they leave a Toyota Land Cruiser with a friend in Nairobi. The vehicle gives them the freedom to stay in the field should a photo opportunity arise. Because giraffes normally take flight when a safari vehicle approaches, Dimijian photographed the two animals in this month's "Natural Moment" from a distance of a quarter mile, using a Nikon F3 with a motor drive, a 600-mm f4 Nikkor lens, and Kodachrome 200 film. In addition to his trips to Kenya, he also photographs nature in Central America and the rain forests of Peru. Dimijian, an assistant professor of psychiatry at the University of Texas-Southwestern Medical School at Dallas, teaches neurobiology and behavior within the evolutionary framework of various animal groups, an interest that is reflected in his photography.

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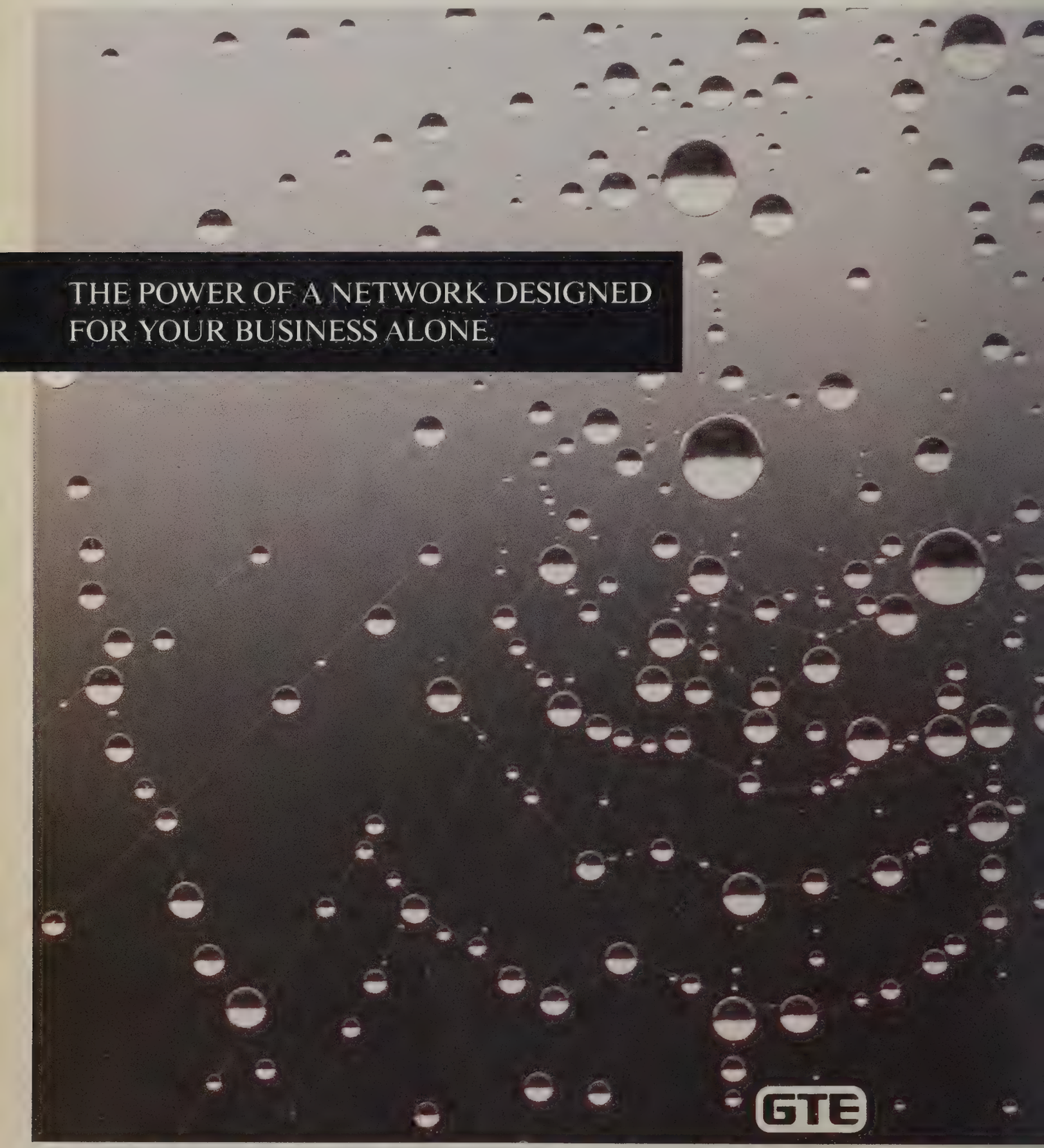

THE POWER IS ON

NATURAL HISTORY

OCTOBER 1989

COVER: *On a sea fan off Bonaire in the Caribbean, a brittle star lies exposed to predators, but the animal has a number of defensive tricks up its long sleeves. Story on Page 72. Photograph by Howard Hall.*

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Skyscraper Cats

In respect to Jared Diamond's "How Cats Survive Falls from New York Skyscrapers" (August 1989), my family's cat, Schatzie, fell twenty-one stories to her death. Her high-rise fall did not enter into the data bank of feline pesematology. It doesn't make us feel any better to know that if she had survived, she would have had a 95 percent chance of recovery. She didn't survive. Here's to all the felines who didn't survive falls and weren't counted.

There once was a cat named Sam
Who fell twenty-one stories, slam!
Since he died on the spot
To the vet went he not
And his death did not count a damn.

Alan Manheim
New York, New York

I would like to congratulate Jared Diamond on his informative and well-balanced treatise on "high-rise syndrome" in cats. There is one more facet of this syndrome that bears examination. A very common injury after blunt trauma is a ruptured urinary bladder. A full bladder may break open much as a water-filled balloon will burst when dropped. However, this injury is rarely seen in high-rise cats. Presumably, these cats empty their bladders while falling. Perhaps they realize, much too late, how frightening it is to be in their predicament.

Robert S. Binder, D.V.M.
Saugus, Massachusetts

Dinosaurs and Education

With regard to "The Dinosaur Ripoff," by Stephen Jay Gould (August 1989), interest in dinosaurs in the United States may be viewed as a natural outcome of the fact that there are more kinds of dinosaurs in this country than there are in any other country—by a wide margin. My tally shows 64 genera from the United States, 39 from Mongolia, 37 from China, 31 from Canada, 26 from England, and 23 from Argentina.

Peter Dodson
Philadelphia, Pennsylvania

Having just read "The Dinosaur Ripoff," I wonder how many of my fellow early childhood teachers reading the same would feel their hearts thumping loudly.

We, who are at the very bottom of the teaching pay scale, are at the very top of time to ignite the firecracker that could burn a lifetime. We, too, find that dinosaurs are the perfect, exciting jumping-off place for all science, and we agree with Gould that peer pressure can force children to hide their proverbial lights under barrels until those lights finally go out. So what do we say to the three- and four-year-olds? We say, "We love you when you share your bugs and your leaves. We love your art because it is yours. Some people are very good at catching balls and othe are very good at finding bugs."

We hope that as these children ent kindergarten, toilet trained, separat from their parents and their blankets; they go off holding their cardboa mortarboards with the stapled yarn tass that they will be able to continue a lo and discovery of science, because the ne teacher loves it too.

Pat Swar
White Plains, New Yo

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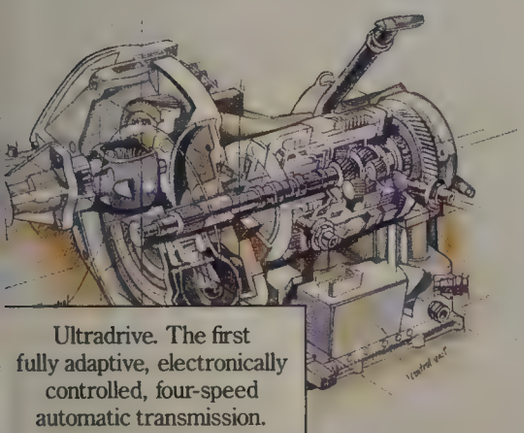

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Death Without Weeping

Has poverty ravaged mother love in the shantytowns of Brazil?

by Nancy Scheper-Hughes

I have seen death without weeping
The destiny of the Northeast is death
Cattle they kill
To the people they do something worse
—Anonymous Brazilian singer (1965)

"Why do the church bells ring so often?" I asked Nailza de Arruda soon after I moved into a corner of her tiny mud-walled hut near the top of the shantytown called the Alto do Cruzeiro (Crucifix Hill). I was then a Peace Corps volunteer and a community development/health worker. It was the dry and blazing hot summer of 1965, the months following the military coup in Brazil, and save for the rusty, clanging bells of N. S. das Dores Church, an eerie quiet had settled over the market town that I call Bom Jesus da Mata. Beneath the quiet, however, there was chaos and panic. "It's nothing," replied Nailza, "just another little angel gone to heaven."

Nailza had sent more than her share of little angels to heaven, and sometimes at night I could hear her engaged in a muffled but passionate discourse with one of them, two-year-old Joana. Joana's photograph, taken as she lay propped up in her tiny cardboard coffin, her eyes open, hung on a wall next to one of Nailza and Ze Antonio taken on the day they eloped.

Nailza could barely remember the other infants and babies who came and went in close succession. Most had died unnamed and were hastily baptized in their coffins. Few lived more than a month or two. Only Joana, properly baptized in church at the close of her first year and placed under the protection of a powerful saint, Joan of Arc, had been expected to live. And Nailza had dangerously allowed herself to love the little girl.

In addressing the dead child, Nailza's voice would range from tearful imploring to angry recrimination: "Why did you leave me? Was your patron saint so greedy that she could not allow me one child on this earth?" Ze Antonio advised me to ignore Nailza's odd behavior, which he understood as a kind of madness that, like the birth and death of children, came and went. Indeed, the premature birth of a stillborn son some months later "cured" Nailza of her "inappropriate" grief, and the day came when she removed Joana's photo and carefully packed it away.

More than fifteen years elapsed before I returned to the Alto do Cruzeiro, and it was anthropology that provided the vehicle of my return. Since 1982 I have returned several times in order to pursue a problem that first attracted my attention in the 1960s. My involvement with the people of the Alto do Cruzeiro now spans a quarter of a century and three generations of parenting in a community where mothers and daughters are often simultaneously pregnant.

The Alto do Cruzeiro is one of three shantytowns surrounding the large market town of Bom Jesus in the sugar plantation zone of Pernambuco in Northeast Brazil, one of the many zones of neglect that have emerged in the shadow of the now tarnished economic miracle of Brazil. For the women and children of the Alto do Cruzeiro the only miracle is that some of them have managed to stay alive at all.

The Northeast is a region of vast proportions (approximately twice the size of Texas) and of equally vast social and developmental problems. The nine states that make up the region are the poorest in the country and are representative of the Third World within a dynamic and rapidly industrializing nation. Despite waves of migrations from the interior to the teeming shantytowns of coastal cities, the majority still live in rural areas on farms and ranches, sugar plantations and mills

Life expectancy in the Northeast is only forty years, largely because of the appallingly high rate of infant and child mortality. Approximately one million children in Brazil under the age of five die each year. The children of the Northeast, especially those born in shantytowns on the periphery of urban life, are at a very high risk of death. In these areas, children are born without the traditional protection of breast-feeding, subsistence gardens, stable marriages, and multiple adult caretakers that exists in the interior. In the hillside shantytowns that spring up around cities or, in this case, interior market towns, marriages are brittle, single parenting is the norm, and women are frequently forced into the shadow economy of domestic work in the homes of the rich or into unprotected and oftentimes "scab" wage labor on the surrounding sugar plantations, where they clear land for planting and weed for a pittance, sometimes less than a dollar a day. The women of the Alto may not bring their babies with them into the homes of the wealthy, where the often sick infants are considered sources of contamination, and they cannot carry the little ones to the riverbanks where they wash clothes because the river is heavily infested with schistosomes and other deadly parasites. Nor can they carry their young children to the plantations, which are often several miles away. At wages of a dollar a day, the women of the Alto cannot hire baby sitters. Older children who are not in school will sometimes serve as somewhat indifferent caretakers. But any child not in school is also expected to find wage work. In most cases, babies are simply left at home alone, the door securely fastened. And so many also die alone and unattended.

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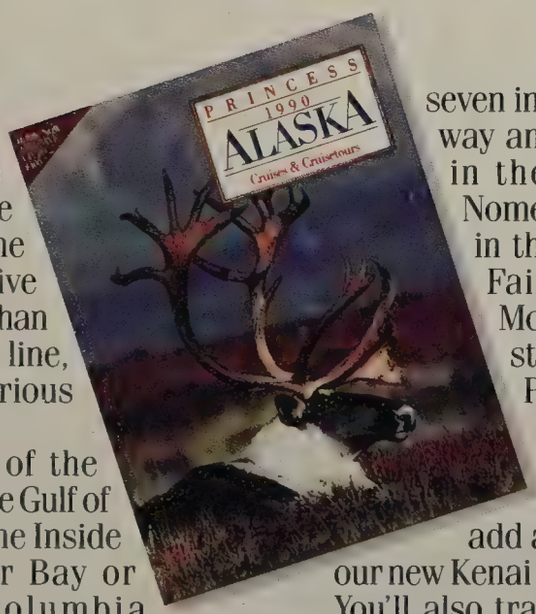

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in the plantation zone of Pernambuco, is within commuting distance of several sugar plantations and mills. Consequently, Bom Jesus has been a magnet for rural workers forced off their small subsistence plots by large landowners wanting to use every available piece of land for sugar cultivation. Initially, the rural migrants to Bom Jesus were squatters who were given tacit approval by the mayor to put up temporary straw huts on each of the three hills overlooking the town. The Alto do Cruzeiro is the oldest, the largest, and the poorest of the shantytowns. Over the past three decades many of the original migrants have become permanent residents, and the primitive and temporary straw huts have been replaced by small homes (usually of two rooms) made of wattle and daub, sometimes covered with plaster. The more affluent residents use bricks and tiles. In most Alto homes, dangerous kerosene lamps have been replaced by light bulbs. The once tattered rural garb, often fashioned from used sugar sacking, has likewise been replaced by store-bought clothes, often castoffs from a wealthy *patrão* (boss). The trappings are modern, but the hunger, sickness, and death that they conceal are traditional, deeply rooted in a history of feudalism, exploitation, and institutionalized dependency.

My research agenda never wavered. The questions I addressed first crystallized during a veritable "die-off" of Alto babies during a severe drought in 1965. The food and water shortages and the political and economic chaos occasioned by the military coup were reflected in the handwritten entries of births and deaths in the dusty, yellowed pages of the ledger books kept at the public registry office in Bom Jesus. More than 350 babies died in the Alto during 1965 alone—this from a shantytown population of little more than 5,000. But that wasn't what surprised me. There were reasons enough for the deaths in the miserable conditions of shantytown life. What puzzled me was the seeming indifference of Alto women to the death of their infants, and their willingness to attribute to their own tiny offspring an aversion to life that made their death seem wholly natural, indeed all but anticipated.

Although I found that it was possible, and hardly difficult, to rescue infants and toddlers from death by diarrhea and dehydration with a simple sugar, salt, and water solution (even bottled Coca-Cola worked fine), it was more difficult to enlist a mother herself in the rescue of a child she perceived as ill-fated for life or better off dead, or to convince her to take back into her threatened and besieged home a baby she had already come to think of as an angel rather than as a son or daughte

I learned that the high expectancy death, and the ability to face child deat with stoicism and equanimity, produce patterns of nurturing that differentiate between those infants thought of as thri ers and survivors and those thought of born already "wanting to die." The surv vors were nurtured, while stigmatize doomed infants were left to die, as mot ers say, *a mingua,* "of neglect." Mothe stepped back and allowed nature to tak its course. This pattern, which I call mo tal selective neglect, is called passive i fanticide by anthropologist Marvin Ha ris. The Alto situation, although cultural specific in the form that it takes, is n unique to Third World shantytown com munities and may have its correlates our own impoverished urban communiti in some cases of "failure to thrive" infant

I use as an example the story Zezinho, the thirteen-month-old toddl of one of my neighbors, Lourdes. I becam involved with Zezinho when I was calle in to help Lourdes in the delivery of a other child, this one a fair and robust litt tyke with a lusty cry. I noted that whi Lourdes showed great interest in the nev born, she totally ignored Zezinho wh wasted and severely malnourished, wa curled up in a fetal position on a piece urine- and feces-soaked cardboard place under his mother's hammock. Eyes ope and vacant, mouth slack, the little bo seemed doomed.

When I carried Zezinho up to the com munity day-care center at the top of th hill, the Alto women who took turns carin for one another's children (in order to fre themselves for part-time work in the can fields or washing clothes) laughed at m efforts to save Ze, agreeing with Lourd that here was a baby without a ghost of chance. Leave him alone, they cautione It makes no sense to fight with death. Bu I did do battle with Ze, and after sever weeks of force-feeding (malnourished ba bies lose their interest in food), Ze bega to succumb to my ministrations. He a quired some flesh across his taut che bones, learned to sit up, and even tried smile. When he seemed well enough, returned him to Lourdes in her miserab scrap-material lean-to, but not witho guilt about what I had done. I wondere whether returning Ze was at all fair Lourdes and to his little brother. But I wa busy and washed my hands of the matte And Lourdes did seem more interested Ze now that he was looking more huma

When I returned in 1982, there wa Lourdes among the women who forme my sample of Alto mothers—still strug gling to put together some semblance

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life for a now grown Ze and her five other surviving children. Much was made of my reunion with Ze in 1982, and everyone enjoyed retelling the story of Ze's rescue and of how his mother had given him up for dead. Ze would laugh the loudest when told how I had had to force-feed him like a fiesta turkey. There was no hint of guilt on the part of Lourdes and no resentment on the part of Ze. In fact, when questioned in private as to who was the best friend he ever had in life, Ze took a long drag on his cigarette and answered without a trace of irony, "Why my mother, of course!" "But of course," I replied.

Part of learning how to mother in the Alto do Cruzeiro is learning when to let go of a child who shows that it "wants" to die or that it has no "knack" or no "taste" for life. Another part is learning when it is safe to let oneself love a child. Frequent child death remains a powerful shaper of maternal thinking and practice. In the absence of firm expectation that a child will survive, mother love as we conceptualize it (whether in popular terms or in the psychobiological notion of maternal bonding) is attenuated and delayed with consequences for infant survival. In an environment already precarious to young life, the emotional detachment of mothers toward some of their babies contributes even further to the spiral of high mortality–high fertility in a kind of macabre lock-step dance of death.

The average woman of the Alto experiences 9.5 pregnancies, 3.5 child deaths, and 1.5 stillbirths. Seventy percent of all child deaths in the Alto occur in the first six months of life, and 82 percent by the end of the first year. Of all deaths in the community each year, about 45 percent are of children under the age of five.

Women of the Alto distinguish between child deaths understood as natural (caused by diarrhea and communicable diseases) and those resulting from sorcery, the evil eye, or other magical or supernatural afflictions. They also recognize a large category of infant deaths seen as fated and inevitable. These hopeless cases are classified by mothers under the folk terminology "child sickness" or "child attack." Women say that there are at least fourteen different types of hopeless child sickness, but most can be subsumed under two categories—chronic and acute. The chronic cases refer to infants who are born small and wasted. They are deathly pale, mothers say, as well as weak and passive. They demonstrate no vital force, no liveliness. They do not suck vigorously; they hardly cry. Such babies can be this way at birth or they can be born sound but soon show no resistance, no "fight" against the common crises of infancy: diarrhea, respiratory infections, tropical fevers.

The acute cases are those doomed infants who die suddenly and violently. They are taken by stealth overnight, often following convulsions that bring on head banging, shaking, grimacing, and shrieking. Women say it is horrible to look at such a baby. If the infant begins to foam at the mouth or gnash its teeth or go rigid with its eyes turned back inside its head, there is absolutely no hope. The infant is "put aside"—left alone—often on the floor in a back room, and allowed to die. These symptoms (which accompany high fevers, dehydration, third-stage malnutrition, and encephalitis) are equated by Alto women with madness, epilepsy, and worst of all, rabies, which is greatly feared and highly stigmatized.

Most of the infants presented to me as suffering from chronic child sickness were tiny, wasted famine victims, while those labeled as victims of acute child attack seemed to be infants suffering from the deliriums of high fever or the convulsions that can accompany electrolyte imbalance in dehydrated babies.

Local midwives and traditional healers, praying women, as they are called, advise Alto women on when to allow a baby to die. One midwife explained: "If I can see that a baby was born unfortuitously, I tell the mother that she need not wash the infant or give it a cleansing tea. I tell her just to dust the infant with baby powder and wait for it to die." Allowing nature to take its course is not seen as sinful by these often very devout Catholic women. Rather, it is understood as cooperating with God's plan.

Often I have been asked how consciously women of the Alto behave in this regard. I would have to say that consciousness is always shifting between allowed and disallowed levels of awareness. For example, I was awakened early one morning in 1987 by two neighborhood children who had been sent to fetch me to a hastily organized wake for a two-month-old infant whose mother I had unsuccessfully urged to breast-feed. The infant was being sustained on sugar water, which the mother referred to as *soro* (serum), using a medical term for the infant's starvation regime in light of his chronic diarrhea. I had cautioned the mother that an infant could not live on *soro* forever.

The two girls urged me to console the young mother by telling her that it was "too bad" that her infant was so weak that Jesus had to take him. They were coaching me in proper Alto etiquette. I agreed, of course, but asked, "And what do *you* think?" Xoxa, the eleven-year-old, looked

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down at her dusty flip-flops and blurted out, "Oh, Dona Nanci, that baby never got enough to eat, but you must never say that!" And so the death of hungry babies remains one of the best kept secrets of life in Bom Jesus da Mata.

Most victims are waked quickly and with a minimum of ceremony. No tears are shed, and the neighborhood children form a tiny procession, carrying the baby to the town graveyard where it will join a multitude of others. Although a few fresh flowers may be scattered over the tiny grave, no stone or wooden cross will mark the place, and the same spot will be reused within a few months' time. The mother will never visit the grave, which soon becomes an anonymous one.

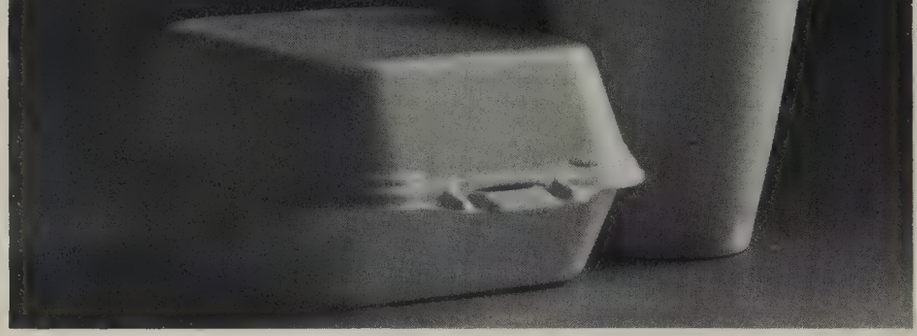
What, then, can be said of these women? What emotions, what sentiments motivate them? How are they able to do what, in fact, must be done? What does mother love mean in this inhospitable context? Are grief, mourning, and melancholia present, although deeply repressed? If so, where shall we look for them? And if not, how are we to understand the moral visions and moral sensibilities that guide their actions?

I have been criticized more than once for presenting an unflattering portrait o poor Brazilian women, women who are after all, themselves the victims of severe social and institutional neglect. I have de scribed these women as allowing some o their children to die, as if this were an unnatural and inhuman act rather than, a I would assert, the way any one of us might act, reasonably and rationally, un der similarly desperate conditions. Per haps I have not emphasized enough the real pathogens in this environment of high risk: poverty, deprivation, sexism, chronic hunger, and economic exploitation. I mother love is, as many psychologists and some feminists believe, a seemingly natu ral and universal maternal script, wha does it mean to women for whom scarcity loss, sickness, and deprivation have made that love frantic and robbed them of their grief, seeming to turn their hearts to stone?

Throughout much of human history— as in a great deal of the impoverished Third World today—women have had to give birth and to nurture children unde ecological conditions and social arrange ments hostile to child survival, as well as to their own well-being. Under circum stances of high childhood mortality, pat terns of selective neglect and passive in fanticide may be seen as active survival strategies.

They also seem to be fairly common practices historically and across cultures In societies characterized by high child hood mortality and by a correspondingly high (replacement) fertility, cultural prac tices of infant and child care tend to be organized primarily around survival goals But what this means is a pragmatic recog nition that not all of one's children can be expected to live. The nervousness abou child survival in areas of northeast Brazil northern India, or Bangladesh, where a 30 percent or 40 percent mortality rate in the first years of life is common, can lead to forms of delayed attachment and a casua or benign neglect that serves to weed ou the worst bets so as to enhance the life chances of healthier siblings, including those yet to be born. Practices similar to those that I am describing have been re corded for parts of Africa, India, and Cen tral America.

Life in the Alto do Cruzeiro resemble nothing so much as a battlefield or an emergency room in an overcrowded inner city public hospital. Consequently, moral ity is guided by a kind of "lifeboat ethics," the morality of triage. The seemingly studied indifference toward the sufferin of some of their infants, conveyed in such sayings as "little critters have no feelings," is understandable in light of these wom



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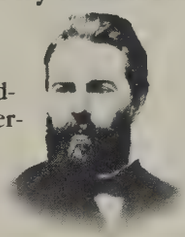

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en's obligation to carry on with their reproductive and nurturing lives.

In their slowness to anthropomorphize and personalize their infants, everything is mobilized so as to prevent maternal overattachment and, therefore, grief at death. The bereaved mother is told not to cry, that her tears will dampen the wings of her little angel so that she cannot fly up to her heavenly home. Grief at the death of an angel is not only inappropriate, it is a symptom of madness and of a profound lack of faith.

Infant death becomes routine in an environment in which death is anticipated and bets are hedged. While the routinization of death in the context of shantytown life is not hard to understand, and quite possible to empathize with, its routinization in the formal institutions of public life in Bom Jesus is not as easy to accept uncritically. Here the social production of indifference takes on a different, even a malevolent, cast.

In a society where triplicates of every form are required for the most banal events (registering a car, for example), the registration of infant and child death is informal, incomplete, and rapid. It requires no documentation, takes less than five minutes, and demands no witnesses other than office clerks. No questions are asked concerning the circumstances of the death, and the cause of death is left blank, unquestioned and unexamined. A neighbor, grandmother, older sibling, or common-law husband may register the death. Since most infants die at home, there is no question of a medical record.

From the registry office, the parent proceeds to the town hall, where the mayor will give him or her a voucher for a free baby coffin. The full-time municipal coffinmaker cannot tell you exactly how many baby coffins are dispatched each week. It varies, he says, with the seasons. There are more needed during the drought months and during the big festivals of Carnaval and Christmas and São Joao's Day because people are too busy, he supposes, to take their babies to the clinic. Record keeping is sloppy.

Similarly, there is a failure on the part of city-employed doctors working at two free clinics to recognize the malnutrition of babies who are weighed, measured, and immunized without comment and as if they were not, in fact, anemic, stunted, fussy, and irritated starvation babies. At best the mothers are told to pick up free vitamins or a health "tonic" at the municipal chambers. At worst, clinic personnel will give tranquilizers and sleeping pills to quiet the hungry cries of "sick-to-death" Alto babies.

The church, too, contributes to the routinization of, and indifference toward, child death. Traditionally, the local Catholic church taught patience and resignation to domestic tragedies that were said to reveal the imponderable workings of God's will. If an infant died suddenly, it was because a particular saint had claimed the child. The infant would be an angel in the service of his or her heavenly patron. It would be wrong, a sign of a lack of faith, to weep for a child with such good fortune. The infant funeral was, in the past, an event celebrated with joy. Today, however, under the new regime of "liberation theology," the bells of N. S. das Dores parish church no longer peal for the death of Alto babies, and no priest accompanies the procession of angels to the cemetery where their bodies are disposed of casually and without ceremony. Children bury children in Bom Jesus da Mata. In this most Catholic of communities, the coffin is handed to the disabled and irritable municipal gravedigger, who often chides the children for one reason or another. It may be that the coffin is larger than expected and the gravedigger can find no appropriate space. The children do not wait for the gravedigger to complete his task. No prayers are recited and no sign of the cross made as the tiny coffin goes into its shallow grave.

When I asked the local priest, Padre Marcos, about the lack of church ceremony surrounding infant and childhood death today in Bom Jesus, he replied: "In the old days, child death was richly celebrated. But those were the baroque customs of a conservative church that wallowed in death and misery. The new church is a church of hope and joy. We no longer celebrate the death of child angels. We try to tell mothers that Jesus doesn't want all the dead babies they send him." Similarly, the new church has changed its baptismal customs, now often refusing to baptize dying babies brought to the back door of a church or rectory. The mothers are scolded by the church attendants and told to go home and take care of their sick babies. Baptism, they are told, is for the living; it is not to be confused with the sacrament of extreme unction, which is the anointing of the dying. And so it appears to the women of the Alto that even the church has turned away from them, denying the traditional comfort of folk Catholicism.

The contemporary Catholic church is caught in the clutches of a double bind. The new theology of liberation imagines a kingdom of God on earth based on justice and equality, a world without hunger, sickness, or childhood mortality. At the same time, the church has not changed its official position on sexuality and reproduction, including its sanctions against birth control, abortion, and sterilization. The padre of Bom Jesus da Mata recognizes this contradiction intuitively, though he shies away from discussions of the topic, saying that he prefers to leave questions of family planning to the discretion and the "good consciences" of his impoverished parishioners. But this, of course, sidesteps the extent to which those good consciences have been shaped by traditional church teachings in Bom Jesus, especially by his recent predecessors. Hence, we can begin to see that the seeming indifference of Alto mothers toward the death of some of their infants is but a pale reflection of the official indifference of church and state to the plight of poor women and children.

Nonetheless, the women of Bom Jesus are survivors. One woman, Biu, told me her life history, returning again and again to the themes of child death, her first husband's suicide, abandonment by her father and later by her second husband, and all the other losses and disappointments she had suffered in her long forty-five years. She concluded with great force, reflecting on the days of Carnaval '88 that were fast approaching:

> No, Dona Nanci, I won't cry, and I won't waste my life thinking about it from morning to night . . . . Can I argue with God for the state that I'm in? No! And so I'll dance and I'll jump and I'll play Carnaval! And yes, I'll laugh and people will wonder at a *pobre* like me who can have such a good time.

And no one did blame Biu for dancing in the streets during the four days of Carnaval—not even on Ash Wednesday, the day following Carnaval '88 when we all assembled hurriedly to assist in the burial of Mercea, Biu's beloved *casula*, her last-born daughter who had died at home of pneumonia during the festivities. The rest of the family barely had time to change out of their costumes. Severino, the child's uncle and godfather, sprinkled holy water over the little angel while he prayed: "Mercea, I don't know whether you were called, taken, or thrown out of this world. But look down at us from your heavenly home with tenderness, with pity and with mercy." So be it.

Nancy Scheper-Hughes is a professor in the Department of Anthropology at the University of California, Berkeley. She is now working on a book on infant death and maternal love in northeastern Brazil. It is slated for publication by Beacon Press in 1991.

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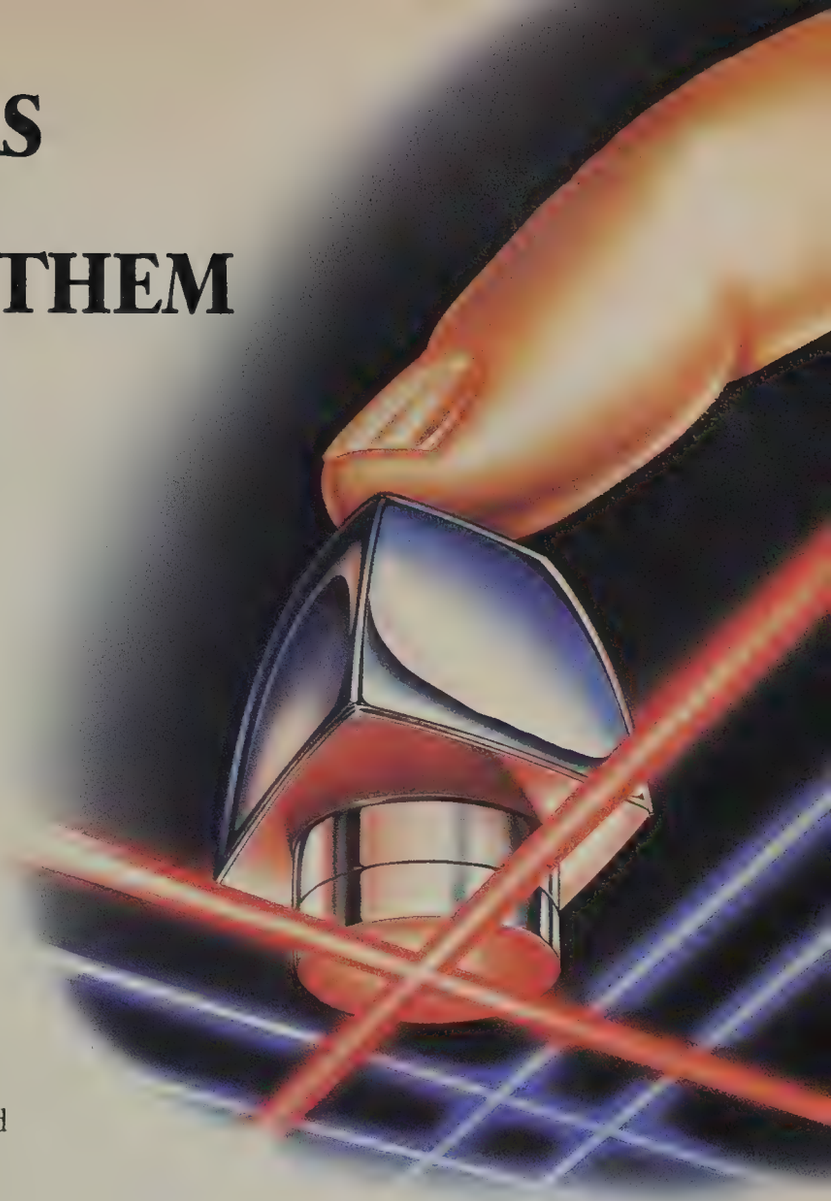

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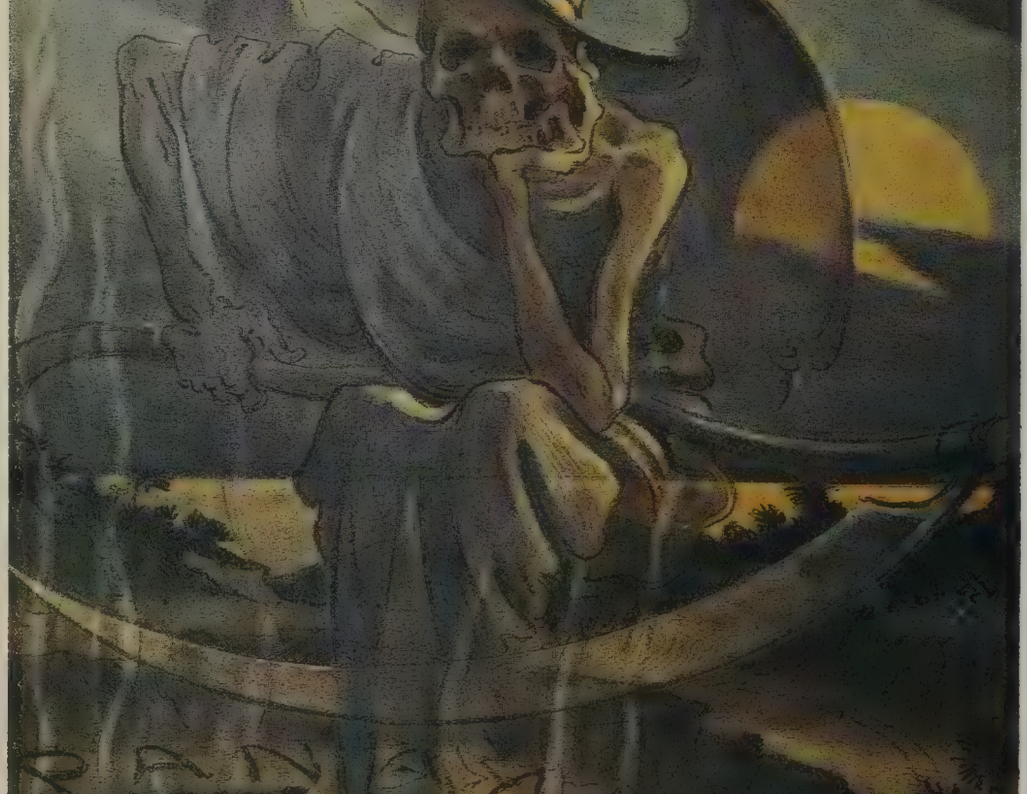
Weeding Out Malaria

American scientists pursue a cure from a Chinese plant

by Daniel L. Klayman

A few years ago, along with five lab colleagues, I spent a sunny August afternoon traipsing through a field along the Potomac River, collecting weeds. The species of greenery we were after had been reported by Chinese scientists to contain a substance effective in treating malaria. Caused by one-celled parasites and spread by the bite of infected mosquitoes, malaria remains one of the world's most insidious diseases. In the 1960s the insecticide DDT, depended upon since World War II to control mosquito larvae but already becoming ineffective against some strains, was shown to be toxic to humans, livestock, and wildlife, and has since been banned in many countries. In addition, once-reliable medicines are rapidly losing their effectiveness as malaria parasites adapt to them. Fortunately, the seemingly useless plants we found growing along th Potomac promise to deliver a new r source in the struggle against the diseas



The Granger Collection

In a 1904 American cartoon, Death awaits those planning to build a canal through Panama's mosquito- and disease-laden swamps.

Known since ancient times, malaria described in certain Egyptian papyrus of the sixteenth century B.C., one of whic notes the association of shivering, feve and spleen enlargement. These symptom were also remarked upon in class Greece, where followers of Hippocrat described the recurrence of fevers at regu lar intervals. They also observed the co nection between marshes and fevers. Se enteenth-century Italians believed tha breathing bad air (*mal aria*) arising fro swamps was responsible for the diseas and in the first half of the nineteent century, the term *malaria* entered th English medical literature (French an Spanish instead have *paludisme* an *paludismo,* respectively, derived from th Latin *palus,* "marsh"). The complex d tails of how mosquitoes transmit the di ease were elucidated less than a centur ago by Sir Ronald Ross, an English phys cian working in India.

In Europe, malaria epidemics histor cally seem to have been intensified b invasion, war, social upheaval, and migra tion, at one time or another afflicting e ery region of the continent. For exampl added to the disruption caused by th Russian revolution, a severe drought an famine led to the temporary migration o inhabitants out of the Volga River basi When in 1923 the river flooded, malari struck the weakened population that ha resettled the area. The epidemic grew t gigantic proportions, even reaching Arc angel on the Arctic Circle.

Whether malaria existed in the Ne World before the arrival of the Spanis explorers is a matter of controversy. Som suggest that the disease first appeare with the importation of slaves from A rica. In any case, malaria became wid

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spread in the United States from New England to California, and epidemics were particularly common along the East Coast and in the South during the Revolutionary War and the War of 1812. The Civil War brought the incidence of the disease to an all-time high, with millions of soldiers affected. By 1900, however, largely as a result of swamp drainage, better nutrition, and increased public awareness, few cases occurred in the area north of the Ohio River, and the United States was nearly free of the disease by the mid-1930s. Elsewhere in the New World, malaria and yellow fever defeated French attempts in the late 1800s to be the first to build a canal in Panama. The American efforts that followed concentrated initially on ridding the Canal Zone of disease-bearing insects.

On the eve of World War II, an estimated one-third of the human race suffered from malaria. Principally through the development and use of DDT, great progress was made against the disease during the war, and a generation ago many scientists believed that malaria would be wiped out by the end of this century. Today, that optimism has faded as malaria continues to be the most prevalent disease on earth, affecting some 200 to 300 million people and causing two to three million deaths annually. Tragically, some one million of those deaths are of children, often under five years of age. Malaria also impedes economic progress in endemic areas, which are typically in tropical, newly developing countries. Recent U. S. Army experiences in Vietnam showed once again how devastating the disease can be to the military. The number of troops evacuated in 1965 because of malaria equaled the number wounded.

Today, malaria exists in much of Africa, South America, Central America, Haiti, the Dominican Republic, and Asia (except Hong Kong, Japan, and Macao). Most of the approximately one thousand cases of malaria in the United States each year are found in immigrants and in U. S. travelers who have visited an endemic area (a limited number of people also acquire the disease from transfusions of infected blood). Newcomers to a malarial region are at great risk of contracting a severe form of the disease. Upon their return home, the symptoms of malaria may be confused with those of more common infections, causing a delay in correct diagnosis and treatment. Prudent travelers nowadays take a prescribed prophylactic drug before entering, while in, and at least one month after departing an infected region.

Malaria may be considered a group of diseases, rather than just one. There a some one hundred different protozoa (one-celled organisms) of the genus *Pla modium* capable of causing malaria, b only four—*Plasmodium vivax, P. ova P. malariae,* and *P. falciparum*—cau the disease in humans. The other plasm dia affect monkeys, livestock, birds, a reptiles. The French surgeon Alphon Laveran, who served in Algeria, is giv credit for first recognizing the malar parasite in human blood, in 1880. Exami ing blood under a microscope for the pre ence of parasites is the best method f diagnosing the disease.

The four species of plasmodia that i fect humans each have somewhat diffe ent life cycles, causing their victims suffer attacks of fever at different a

Nineteenth-century illustration, reprinted in J. W. Bastien, *Healers of the Andes*

The cinchona tree is the source of quinine, the world's first antimalarial drug.

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characteristic intervals. *P. falciparum* is the species most often responsible for causing death. In its advanced form, known as cerebral malaria, falciparum malaria causes a high fever, rapid pulse rate, intense headaches, convulsions, seizures, and coma. Left untreated, cerebral malaria can be fatal and probably causes 80 percent of malaria deaths. This form of the disease is seen particularly in children aged four to fourteen and in foreign visitors to endemic areas. Pregnant women, because of the heavy demands already placed upon their immune systems, are also strongly affected by malaria. Untreated or improperly treated, the disease can cause anemia in these women. This may kill them or the fetus or result in the birth of a low-weight infant. Falciparum malaria is probably responsible for most maternal deaths in the tropics.

Malaria is spread by the bite of a mosquito that has the infective stage of the malaria parasite in its salivary gland. Only a few species of the genus *Anopheles* (there are about 150 different species) carry human malaria parasites, and only the female mosquito requires a blood meal and has a bite that can penetrate the skin. The mosquito injects her saliva into her victim to inhibit clotting during feeding, and this provides the opportunity for the parasite to enter the bloodstream. Within an hour, the organisms congregate in the liver and begin multiplying.

Falciparum parasites develop in the liver for about twelve days, then enter the red blood cells, where they undergo further changes and multiplication. After a development period of one to four days, the parasites, called merozoites at this stage, burst out of the red blood cells, causing the recently infected person to experience the first clinical symptoms of the disease, chills with rising temperature, followed by fever and intense sweating. Falciparum parasites also make the red cells adhere to blood vessels, causing clumps that obstruct the flow of blood to various organs, including the brain, liver, and kidneys.

Some merozoites reinfect other red cells, where they again multiply, and the rupturing of red cells, which occurs approximately every forty-eight hours, repeatedly causes chills and fever in the patient. Other merozoites develop into gametocytes, the sexual form of the parasite. An uninfected mosquito renews the cycle when she bites one or more infected persons and acquires male and female gametocytes from the blood. Over the next ten to twenty-one days, in the lining of the mosquito stomach, the gametocytes unite in the process of fertilization, and the resultant zygotes migrate to the insect's sa vary glands, ready to be transmitted to new victim. (In temperate zones, mosqu toes die in the winter, and so the disease not carried during that time to new inc viduals; but humans serve as repositori of the infection.)

In endemic areas, people who survi falciparum malaria infection during chil hood develop a degree of immunity to th disease. Although they may contract repeatedly, they suffer milder sympton and the infections do not last as lon Young children have only a limited degr of immunity, passed on to them by the mothers during pregnancy. In additio nutritional deficiency in iron seems to pr tect some children from the disease. Pe ple living in endemic areas may also hav genetic traits that give them an extra me sure of protection. In Africa, for exampl individuals who have the gene that caus sickle-cell anemia have fewer serious e fects of falciparum malaria (see "Bloo Genes, and Malaria," by Jared Diamon *Natural History,* February 1989). D spite considerable effort, scientists hav not yet succeeded in developing a vacci against malaria.

Until the 1630s there was no reliab treatment for the disease. Then came qu nine. Probably no other medicine has more romantic early history. The standar story has been that during the mid-seve teenth century the Incas of Peru revealed to the Jesuit missionaries the fever-redu ing powers of the bark of a certain mou tain-growing evergreen tree they calle *quina-quina.* The Jesuits, in turn, use infusions of the powdered bark to cure Spanish governor and other influenti colonists afflicted with malaria. Amon those treated, supposedly, was the Co dessa de Chinchon, wife of the Viceroy Peru. Impressed with its curative power she brought the bark to Europe in 164 At first greeted with skepticism, the pow dered bark was eventually accepted as legitimate remedy and became worth i weight in gold. In 1742, the renowne taxonomist Linnaeus named the tree *ci chona* after the Condessa de Chincho Historic investigations of recent year however, suggest that the Condessa neve had malaria, never partook of the bar and never returned to Spain. She is b lieved to have died of the bubonic plagu in Cartagena, Colombia.

In 1820, the French chemists Pier Pelletier and Joseph Caventou isolated very bitter white powder from the ci chona bark and called it quinine, aft *quina-quina.* It falls within a class chemicals called alkaloids—organic com pounds that contain nitrogen atoms ar

re physiologically active. Quinine has een the most widely used antimalarial rug and is the standard against which all thers are measured. As with virtually all rugs, whether naturally derived or synnetic, quinine has side effects. High doses an cause tinnitus (ringing in the ears) and lurred vision, although these disturances disappear upon withdrawal of the rug. Quinine can also bring on premature abor in women who are in an advanced tage of pregnancy.

The two world wars cut off belligerents rom their quinine supplies and spurred he development of synthetic antimalarial rugs that could be manufactured from elatively inexpensive and readily availble starting materials. The first crisis ocurred during World War I, when German shipping was prevented by the Allies from reaching cinchona sources. Several synthetic drugs were tested, but they were of limited value. Later, in 1930, the drug atebrin was developed in Germany and enjoyed considerable use, even though at therapeutic dose levels it may turn the skin yellow. The initial research paved the way for a second generation of synthetic antimalarials, necessitated by the Japanese seizure of the cinchona plantations in Java during World War II.

Among the important drugs developed by the American and European crash program from 1941 to 1946 are chloroquine (which German scientists actually first made in 1934, but then abandoned because they thought it was too toxic) and amodiaquine. These drugs are used for both treatment of the disease and prophylaxis. The Korean War led to the use of primaquine. Other drugs to emerge in recent decades include proguanil and pyrimethamine. Each may act differently, halting the life cycle of the parasite at a different stage. Many of these drugs have therapeutic properties that make them superior to quinine. (Because of the increased reliance on synthetic antimalarials, most of the world's production of quinine is now channeled into providing the flavoring for tonic water.)

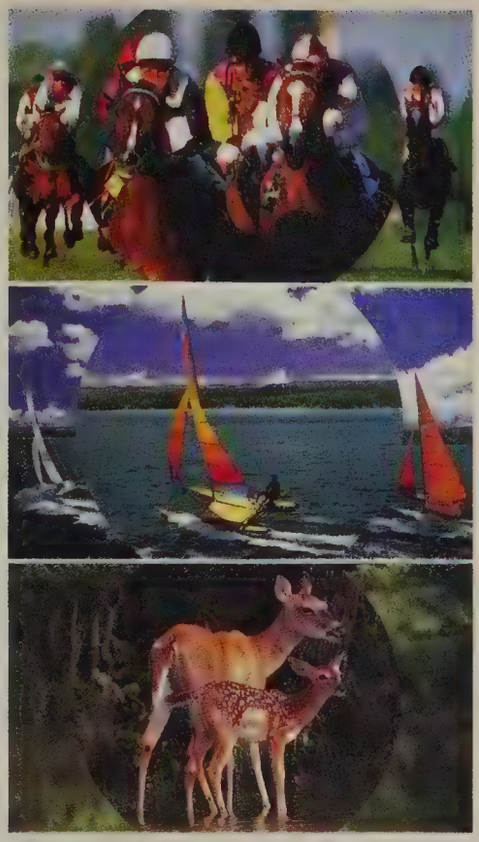
A problem with many widely used drugs is that in time, unless a disease is rapidly and completely wiped out, strains of the disease-producing organism tend to emerge through mutation and natural selection that are resistant to treatment. Things were going fairly smoothly in the treatment of malaria until 1960, when a report appeared that described a form of falciparum malaria in Colombia that did not respond to treatment by the most popular antimalarial drug, chloroquine. Since then, resistance to chloroquine has developed in large regions of South America, East Africa, and Southeast Asia.

At first, people infected with resistant organisms could be treated with alternate drugs, but several other once-dependable drugs, such as pyrimethamine, are also beginning to fail in some cases. This suggests the appearance of strains of falciparum plasmodia that are resistant to more than one drug. Aware of the urgent need for new drugs, the U. S. Army began its antimalarial drug development program in 1963; mefloquine and halofantrine are the products of this effort that are now in use. Some scientists also hope to develop supplementary drugs to overcome the resistance of parasites.

About twenty years ago, Chinese scientists also involved in malarial research began to investigate whether an herb that

aniel L. Klayman

A new source of antimalarial drugs, Artemisia annua *takes Manhattan.*



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grew there could be beneficial in the treatment of malaria. For many centuries, a pervasive weed had been claimed as useful in reducing fevers. The great Chinese herb doctor Li Shi-zen, for example, in his treatise of 1527, had recommended soaking *qing hao* (meaning "green herb" and pronounced "ching-how") in cold water and giving the resultant infusion to the feverish patient. Modern experiments in which a hot tea was made of the dried plant disappointingly failed to benefit malaria-infected mice. Later attempts, however, using an organic solvent with a low boiling point, yielded an extract that gave positive results.

Encouraged by the tests, Chinese chemists proceeded to find out which of the numerous constituents in the extract made it effective. They isolated a single substance, a white crystalline powder they called *qinghaosu,* meaning "extract of green herb." By coincidence, this same substance, now known in the West as artemisinin, had also been isolated a few years earlier from the same plant growin in Yugoslavia by a group from the Unive sity of Belgrade. The Belgrade scientist however, had no idea of its potential m dicinal qualities, nor did they propose i correct structural formula.

Chemically, artemisinin may be categ rized as a terpene, a class of compound that is responsible for the odor of mos aromatic plants. Unlike quinine and a other antimalarial drugs, the artemisini molecule lacks nitrogen atoms, which ar common to all alkaloids. Its striking chem ical feature is an atomic grouping rare fo a naturally derived material, a linked pa of oxygen atoms, known as a peroxid group. The pair of oxygen atoms join tw parts of the carbon framework of th artemisinin molecule, and when the mole cule breaks apart, they give artemisini weak oxidizing properties, not unlike d lute household hydrogen peroxide. Test with closely related materials prove tha the peroxide group of artemisinin is th crucial portion of the molecule and that i

Daniel L. Klayman

A. annua *offers new hope in combating resistant strains of malaria parasites.*

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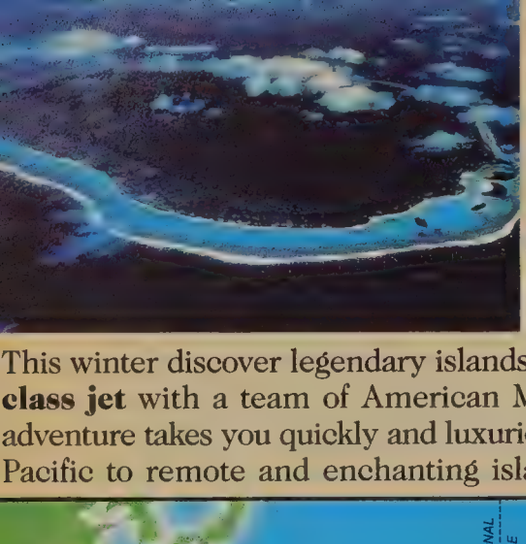

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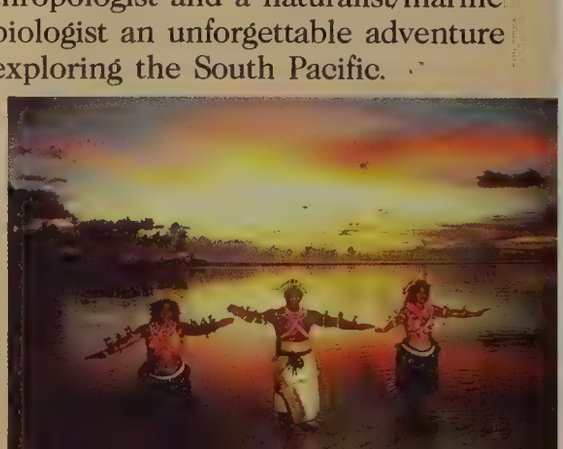

acts by destroying the cell membrane of the malaria parasite.

In China, large doses of artemisinin have been administered to various laboratory animals, and the chemical appears considerably less toxic than quinine, chloroquine, and other existing drugs. The Chinese have also tested artemisinin in humans infected with chloroquine-susceptible and chloroquine-resistant strains of falciparum malaria. Both tablets and an injectable form acted rapidly to lower fevers and eliminate parasites from the blood. On the negative side, however, the drug is short acting; many patients experienced a return of the malaria infection within one month and required further treatment with synthetic drugs.

Learning of the Chinese research, my colleagues and I at the Walter Reed Army Institute of Research wanted to evaluate artemisinin further. Fortunately, its source, the inconspicuous and pleasant smelling plant known to Western botanists as *Artemisia annua* (and by the common names sweet Annie, annual wormwood and sweet wormwood) was located for us flourishing along the banks of the nearby Potomac, by biologist Ted Bradley of George Mason University. As indicated by its name, *A. annua* is an annual, which starts its growth with fernlike leaves in April and achieves a height of six to twelve feet by September.

Whereas the plant grows profusely in China, it is found in the United States in only limited quantity along the banks of several eastern rivers (quite unexpectedly, too, I found it growing vigorously in vacant lots in lower Manhattan). *A. annua* is not believed to be native to North America, suggesting that its seeds came on merchant vessels that traveled to the Orient. It grows wild in many other countries as well, including Yugoslavia (as already mentioned), Hungary (where it is cultivated for its aromatic oil), Bulgaria, Romania, Spain, Turkey, and Argentina.

My colleagues and I have cultivated it without difficulty despite our nonagronomic background. Recently, with seeds we provided, researchers have grown the plant on an experimental basis in the Indian state of Kashmir, in the Bombay area, and in Calcutta. Ironically, the tropics, where malaria is endemic, do not appear to be good places to grow the plant, which apparently requires certain seasonal changes in day length. Artemisinin has been synthesized by chemists, first in Switzerland and later in China and the United States, but the processes are so costly that at present only the natural product can be used for pharmaceutical purposes.

The plants we collected were dried in

the sun and the leaves ground to a coarse powder, which was soaked for one to two days in an organic solvent. The resultant extract was then filtered and separated into its constituents to obtain a small quantity of pure artemisinin. We later determined that the artemisinin content of the leaves is at a maximum in late July to early August, immediately before the plant forms its numerous small, pale yellow flowers. The stem and root are devoid of artemisinin. Some other well-known artemisia species are *A. dracunculus* (tarragon), *A. absinthium* (constituent of the now illegal toxic drink absinthe), and *A. tridentata* (sagebrush). Of approximately 400 known species of artemisia, we have examined about 100 for the presence of artemisinin, but so far have found it in none except *A. annua*.

One problem with artemisinin is that it dissolves poorly in media used for injections, such as oil or, preferably, water. Chinese chemists have made more than fifty chemically modified types of artemisinin looking for a derivative with greater oil solubility. After testing these derivatives in mice, the best one was identified and named artemether. It has even greater antimalarial potency than its parent, artemisinin, and allows fewer relapses. Artemether in an oil solution, administered by intramuscular injection, is currently available in Chinese hospital pharmacies in Hainan Island and other areas where chloroquine-resistant malaria is found. Another oil-soluble derivative, arteether, is being developed by the World Health Organization in conjunction with scientists at the Walter Reed Army Institute of Research.

Chinese chemists also created a water-soluble derivative, sodium artesunate, that can be administered intravenously, the route by which drugs are most rapidly absorbed. It is especially useful in the treatment of cerebral malaria, where rapid action is critical. Drugs such as quinine and chloroquine have been given intravenously for cerebral malaria and have shown results after one to two days. But a typical comatose patient treated with sodium artesunate has a rapid reduction in the number of parasites and regains consciousness, on average, in twelve hours.

Sodium artesunate has two drawbacks, however. The first is that relapses are common in some apparently cured patients, necessitating the administration of more traditional antimalarials after the patient regains consciousness. The second problem is its instability. Within a few hours after sodium artesunate is dissolved in water, it starts decomposing, reducing the potency of an intravenous infusion. Our research group, aware of this instability, synthesized several new water-soluble artemisinin derivatives, the most promising of which we call sodium artelinate. This compound appears to be as effective as sodium artesunate and has the advantage of being stable in water solution for more than two months.

Further testing is now taking place in owl monkeys infected with (human) falciparum malaria. If the drug shows high efficacy and low toxicity, several years of additional detailed evaluation in laboratory animals, as well as in humans, will be required before it can be used clinically. Nevertheless, malaria specialists are excited by the artemisinin class of drugs, not only because it is the first since quinine to be derived from a natural source but also because it represents a promising new weapon against drug-resistant malaria.

Daniel L. Klayman is the head of the organic chemistry section in the Division of Experimental Therapeutics at Walter Reed Army Institute of Research, Washington, D. C.

Full of Hot Air

Errors are inevitable byproducts of scientific daring, and even Darwin made some beauts

by Stephen Jay Gould

Fiorello La Guardia may be destined to go down in history primarily as godfather to an airport. But he was a great mayor for New York in tough years of depression and war. (My birth certificate even bears his signature—well, at least a stamped version.) He also possessed in abundance the trait that we find most welcome, but encounter all too rarely, in people of accomplishment—a willingness to acknowledge occasional and inevitable error. In his most famous quip, La Guardia once remarked, "When I make a mistake it's a beaut!"

During the current silly season in Washington, as two congressional committees seem intent on legislating against error in scientific papers, we should pause to consider the essential distinction between fraud (the supposed subject of these official investigations) and mistakes. Fraud is a social and psychological pathology, although science can and must police itself. Error is the inevitable byproduct of daring—or of any concentrated effort for that matter. You might as well legislate against urination after beer drinking.

No great work of science has ever been free of error, and any extensive or revolutionary work must contain a few of La Guardia's beauts. Intellectual progress is a complex network of false starts and excursions into trial and error. Darwin's *Origin of Species,* for example, sprinkles numerous errors into its ocean of reforming validity. The errors are so frequent, and so varied, that we might even try to establish categories.

Darwin, first of all, commits several errors of fact. Here I would skip the dull and quotidian misreporting of information and concentrate on the far more interesting errors based on predictions from theoretical premises that turn out to be false or exaggerated. Darwin's commitment to gradualism, for example, led him to make at least two prominent, and outstandingly wrong, conjectures: (1) He gave a time of more than 300 million years for the "denudation of the Weald" (the erosion of the region, forty miles wide, between the north and south Chalk Downs in southern England), based on his belief in the steady, grain-by-grain character of geological change. But alteration need not proceed so slowly, or so continuously, and the actual time is one-third to one-fifth of Darwin's generous allotment. (2) Multicellular animal life begins with geological abruptness at the "Cambrian explosion" some 570 million years ago. Darwin, who rejected biological rapidity even more zealously than the geological variety, predicted that the "explosion" must be illusory and that the pre-Cambrian history of multicellular life must be as long as, or longer than, the 570 million years of success ever since. We now have an excellent record of pre-Cambrian life—all of it single-celled until just before the Cambrian explosion.

A second category might be called errors of judgment: political miscalculations really. The savvy Darwin made few mistakes in this mode, but he slipped occasionally by giving free rein to fatuous speculations in a treatise that gained its power by sinking a weighty anchor in sober fact and avoiding the fanciful conjectures of previous writing about evolution. In a passage that he would later rue, and that gave aid, comfort, rhetorical advantage, and belly laughter to the enemy Darwin wrote:

> In North America the black bear was seen by Hearne swimming for hours with widely open mouth, thus catching, like a whale, insects in the water .... If the supply of insects were constant, and if better adapted competitors did not already exist in the country, I can see no difficulty in a race of bears being rendered, by natural selection, more and more aquatic in their structure and habits, with larger and larger mouths, till a creature was produced as monstrous as a whale.

(Later editions of the *Origin* kept the first factual sentence and expunged all the rest.) A statement like this need not be false (indeed, as a speculation, we cannot tell); the important thing, as Machiavelli would have said, is to avoid the appearance of silliness.

A third category, perhaps the most revealing, includes mistakes that most of us don't recognize because we make them ourselves. Call them errors of thoughtless convention. I include here those passive repetitions of standard cultural assumptions stated so automatically, or so deeply (and silently) embedded within the structure of an argument, that we scarcely detect their presence. Darwin may have been the greatest intellectual revolutionary of the nineteenth century, but he made a few outstanding errors in this category most related to his ambiguity on the great bugbear of progress—a concept that had no place in the basic mechanics of natural selection, but that Darwin, as an eminent Victorian, could not abandon entirely.

Consider Darwin's treatment of the evolution of vertebrate lungs and their

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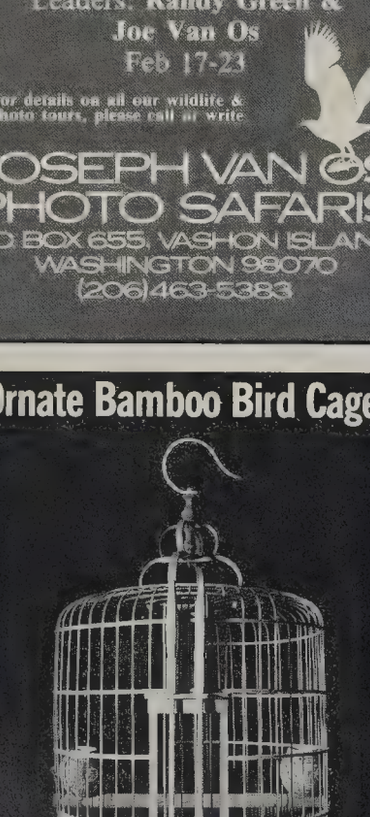

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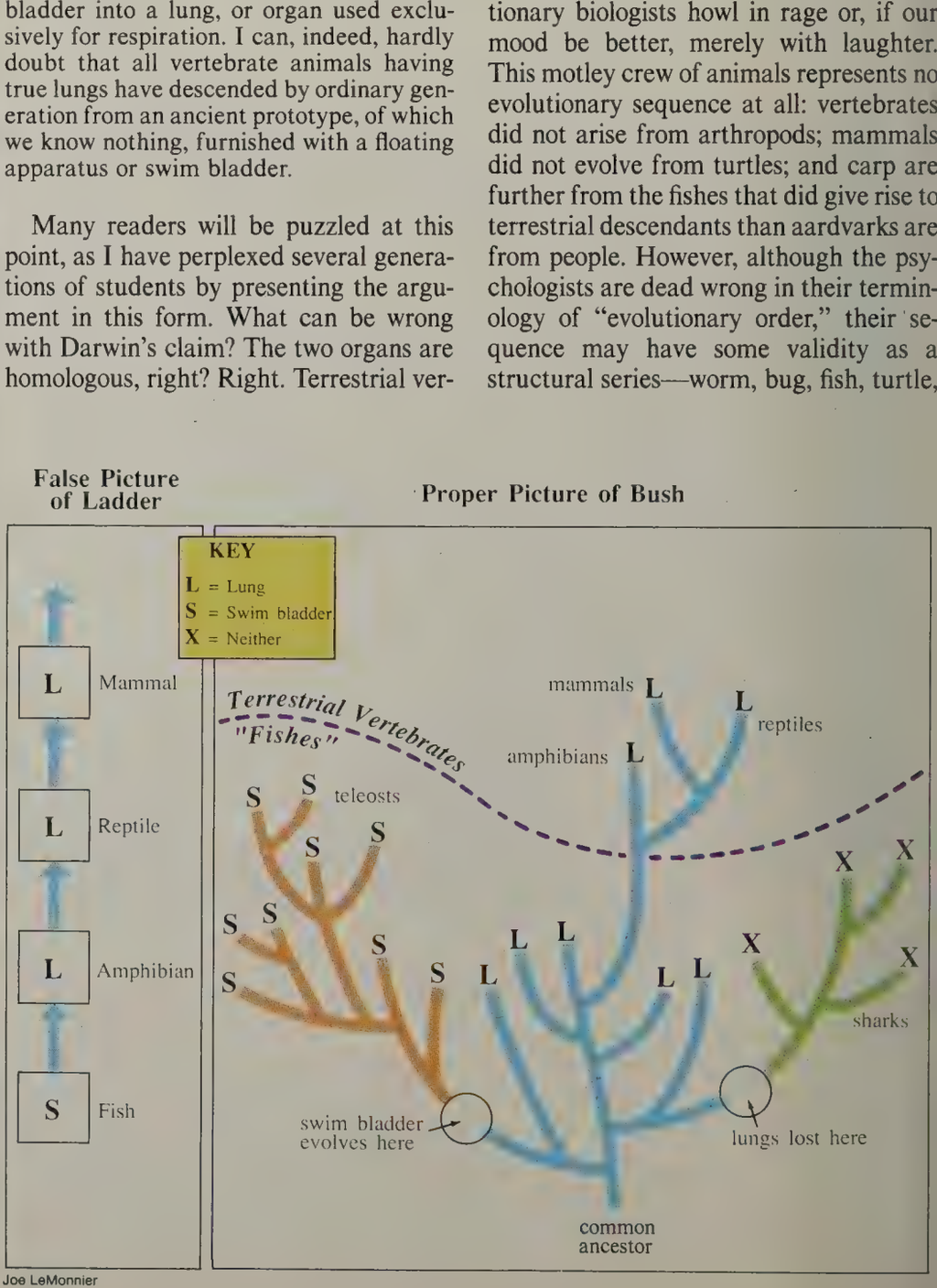
relationship with the swim bladders of bony fishes—an example that Darwin obviously viewed as important to his general argument because he repeats the story half a dozen times in the *Origin*. Darwin begins by noting, correctly, that the lung and swim bladder are homologous organs—different versions of the same basic structure, just as a bat's wing and a horse's foreleg share a common origin indicated by the similar arrangement of bones in body parts that now work in such different ways. But Darwin then draws a false inference from the fact of homology. He claims, with increasing confidence ending in certainty, that lungs evolved from swim bladders:

> All physiologists admit that the swim bladder is homologous . . . in position and structure with the lungs of the higher vertebrate animals; hence there seems to me to be no great difficulty in believing that natural selection has actually converted a swim bladder into a lung, or organ used exclusively for respiration. I can, indeed, hardly doubt that all vertebrate animals having true lungs have descended by ordinary generation from an ancient prototype, of which we know nothing, furnished with a floating apparatus or swim bladder.

Many readers will be puzzled at this point, as I have perplexed several generations of students by presenting the argument in this form. What can be wrong with Darwin's claim? The two organs are homologous, right? Right. Terrestrial vertebrates evolved from fishes, right? Yes again. So lungs must have evolved from swim bladders, right? Wrong, dead wrong. Swim bladders evolved from lungs.

I love this example, especially as a pedagogical tool, because an outstandingly counterintuitive assertion—the evolution of swim bladders from lungs—becomes the favored hypothesis with sudden and stunning clarity as soon as we shed a common, disabling assumption and start considering the question in a different light. The problem lies with a chronic confusion—abetted by cultural prejudice in this case—between structural sequence and branching order.

The literature of experimental psychology often reports comparative data of performance on various tests for learning in, say, a planarian worm, a crab, a carp, a turtle, and a dog. These are often reported as an "evolutionary sequence" of mental advance. Such statements make evolutionary biologists howl in rage or, if our mood be better, merely with laughter. This motley crew of animals represents no evolutionary sequence at all: vertebrates did not arise from arthropods; mammals did not evolve from turtles; and carp are further from the fishes that did give rise to terrestrial descendants than aardvarks are from people. However, although the psychologists are dead wrong in their terminology of "evolutionary order," their sequence may have some validity as a structural series—worm, bug, fish, turtle,



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and dog might express some increasing property of neurological functioning.

When we turn to another common sequence—fish, amphibian, reptile, mammal, monkey, human—the problems intensify, for now we cannot even speak of a legitimate structural sequence. Frogs live in different places, but are they "higher" than swordfishes or sea horses? What odds would you put on a ground sloth going up against a *Triceratops*? Fine, you say; no necessary progress here, but surely this venerable lineage records *the* path of vertebrate evolution. And now we come to the crux of the error about lungs and swim bladders. If this sequence is *the* path of vertebrate change, then swim bladders must evolve to lungs, as Darwin said—for the canonical fish, the first member of the series, has a swim bladder, while all of us at the top have lungs.

But we wallow in a double confusion when we make this "intuitively obvious" assertion—first, the false assumption of progress, which makes the lung a "higher" organ than a swim bladder and thus unfit for creatures on the bottom; second, and more seriously, the confusion of ladders and bushes, or sequences and branching orders. Fish-amphibian-reptile-mammal is not *the* road of change among vertebrates; it represents only one pathway among thousands in the complexly branching bush of vertebrate evolution (the chart on page 30 should make my argument clear). All the other pathways lead to creatures that we continue to call "fish" in the vernacular. In terms of variety in anatomical design, we find far more diversity among the creatures called fish than among all the terrestrial vertebrates put together. The terrestrial line is a single branch, with astounding success to be sure, but with limited diversity in underlying anatomical structure (whatever the outward variety of flying birds, slithering snakes, and thinking people). By contrast, fishes are astoundingly disparate in basic design and include lineages that separated a hundred million years before any terrestrial vertebrate arose. Consider the jawless lampreys, the boneless sharks (also lacking either lung or swim bladder), and the odd coelacanth; don't confine your image to the canonical creature impaled on a hook at the end of your rod and line.

Yes, that canonical creature—called a teleost, or member of the vast group of "higher" bony fishes—generally has a swim bladder. But teleosts, although they include almost all common fishes today, are evolutionary latecomers, almost surely arising in the sea long after mammals first evolved on land. Yes, they have swim bladders, and they are fish—but they are

not ancestors to any terrestrial vertebrate. Their status, as late and derived, leaves entirely unresolved the issue of what came first: swim bladders or lungs.

A reconstruction of vertebrate branching order gives a clear answer to this question: Darwin was wrong; ancestral vertebrates had lungs. (The details of this argument are well expressed by Karel F. Liem, in "Form and Function of Lungs: The Evolution of Air Breathing Mechanisms," *American Zoologist,* volume 22, pages 739–59.) The first vertebrates maintained a dual system for respiration: gills for extracting gases from seawater and lungs for gulping air at the surface. A few modern fishes, including the coelacanth, the African bichir *Polypterus,* and three genera of lungfishes, retain lungs. One major group, the sharks and their allies, lost the organ entirely. In two major lineages of derived bony fishes—the chondrosteans and the teleosteans—lungs evolved to swim bladders by atrophy of vascular tissue to create a more or less empty sac and, in some cases, by loss of the connecting tube to the esophagus (called the trachea in humans and other creatures with lungs). Some fishes retain the connection of swim bladder with esophagus; they can inflate their swim bladders by gulping air at the surface. Fishes with separate swim bladders usually extract gases from blood flowing through an extremely fine and rich system of vessels surrounding the bladder and possessing one of the loveliest technical names in all biology—the *rete mirabile,* or "wondrous network."

I would not wish to issue overt praise for mistakes, but Darwin's error on the swim bladder falls into the category that we welcome as particularly instructive, for correction involves a sudden shift from the "can't be" to the completely obvious—that almost thrilling property of scales falling from eyes. The agent of correction, moreover, is not a new and pristine fact (bringing pleasure mixed with little general instruction), but a shift in an underlying conceptual structure that might just reorient a view of life.

Let us then praise Darwin's fruitful error on this basis, but also for another, and even more important, reason. Darwin may have gotten his sequence backward, but he was using the story to illustrate a vital and widely misunderstood principle of evolutionary theory—and the illustration works just as well whether swim bladders evolve to lungs or vice versa. Why, then, was Darwin so interested in this issue in the first place?

One common argument against evolution held (and still holds among the linger-

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ing opposition) that small changes within a "basic kind" might occur, producing the range from Chihuahua to Great Dane, or Shetland pony to old dobbin hauling the Budweiser truck. But transitions between types are forbidden because fundamental novelties cannot arise by evolution. The classic form of this argument holds that since "novel" structures often arise (or so evolutionists claim) from ancestral organs with strikingly different functions, transitional forms would be inviable because they would exist in the never-never land of utter unworkability, with one key function degenerated and another not quite established. To cite a classic case (with an elegant resolution as we shall see), how could reptiles evolve into mammals if bones that articulate the reptilian jaw must evolve to the malleus and incus (hammer and anvil) of the mammalian middle ear? No intermediary form could live without a jaw articulation, as the leisurely earward transition occurred. In other words, both the "before" and the "after" make sense as functional organisms, but the "in between" doesn't work.

Lung and swim bladder represent a classic example of this dilemma, whichever way the sequence proceeded. The organs are homologues, and one presumably evolved to the other. But how could the transitional form have survived, either stuck like a lead weight on the bottom as buoyancy failed, while breathing required access to the surface; or raring to float but gasping for breath?

Darwin begins by warning us against a priori claims of impossibility in principle, for multifarious nature so often gets the last laugh over this particular form of human vanity: "We should be extremely cautious in concluding that an organ could not have been formed by transitional gradations of some kind." Darwin's ingenious solution involves a double linkage of one-for-two, with two-for-one—mysterious when stated so abstractly, but beautifully simple by illustration, with lungs and swim bladders as a primary example. First, Darwin tells us, single organs often perform more than one function—one-for-two:

> Numerous cases could be given . . . of the same organ performing at the same time wholly distinct functions . . . . In such cases natural selection might easily specialize, if any advantage were thus gained, a part or organ, which had performed two functions, for one function alone, and thus wholly change its nature by insensible steps.

The primitive swim bladder, Darwin argues (and we may reverse the argument for lungs), may also have worked in a subsidiary way in gas exchange—and this latter role may have been intensified, as the original use dropped out, in the evolution of the lung. But the one-for-two principle cannot resolve the problem of intermediary stages—for how could a fish breathe as the original lungs lost their primary function?

Darwin therefore calls upon his second, coupled principle of two-for-one. Many vital functions are performed by two or more organs, and one can change so long as the other continues to play the needed role. We can breathe through both our nose and mouth—and thank goodness, or we would all be dead of colds:

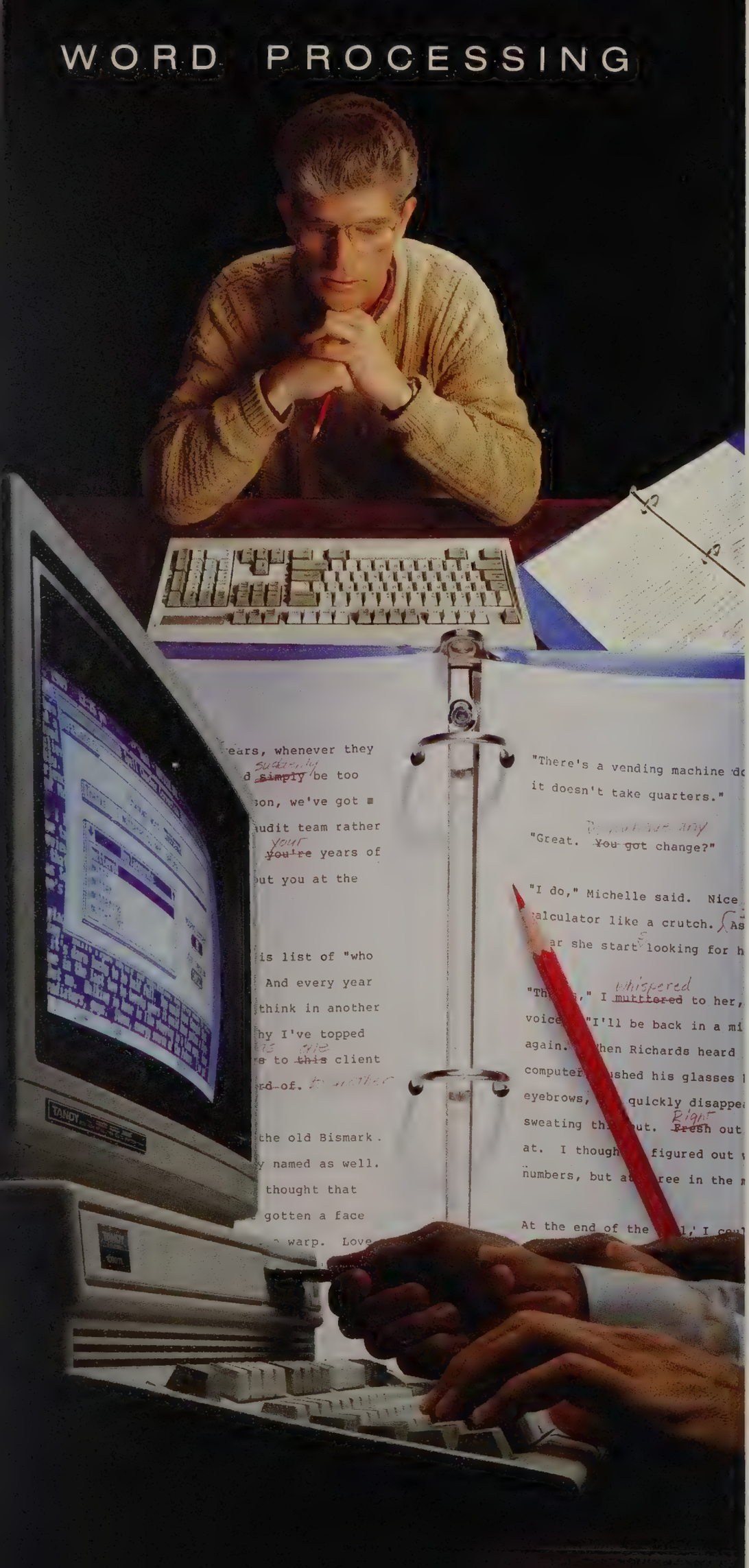
> Two distinct organs sometimes perform simultaneously the same function in the same individual . . . . In these cases, one of the two organs might with ease be modified and perfected so as to perform all the work by itself; . . . and then this other organ might be modified for some other and quite distinct purpose.

We can now understand why Darwin liked the example of lungs and swim bladders so much. He had made a reasonable conjecture about one-for-two in arguing for supplementary respiration in swim bladders; and he had definite evidence about two-for-one in the presence of numerous living fishes with dual systems of breathing—gills and lungs. (The official taxonomic name of the lungfishes, Dipnoi, means "two breathing.") Thus, using lungs and swim bladders as his key example in a central defense of large-scale evolution, Darwin concluded:

> For instance, a swim bladder has apparently been converted into an air-breathing lung. The same organ having performed simultaneously very different functions, and then having been specialized for one function; and two very distinct organs having performed at the same time the same function, the one having been perfected whilst aided by the other, must often have largely facilitated transitions.

Readers might fairly balk at this point. The argument coupling one-for-two and two-for-one is logically sound, but doesn't it smack of special pleading and gross improbability? How often can you expect to find such a combination? Perhaps both situations are uncommon; their conjunction would then be nearly incomprehensible. Rare times rare equals rare squared, or effectively impossible.

But we now come to the true beauty of Darwin's argument. Neither situation is rare, and the two phenomena—one-for-two and two-for-one—are not really separate at all. Both are expressions of a deeper, and profoundly important, principle —*redundancy* as the ground of creativity in any form. They are two sides of



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The notion that organs are "for" particular things, ideally suited for one and only one job, is a vestige of old-style creationism—the idea that God made each creature, fully formed and perfect in function. If each organ existed explicitly for a single role, then I suppose that one organ doing more than one thing would be rare, and that two organs doing the same thing might be even rarer. But organs were not designed for anything; they evolved—and evolution is a messy process brimming with redundancy. An organ might be molded by natural selection for advantages in one role, but anything complex has a range of other potential uses by virtue of inherited structure—as we all discover when we use a dime for a screwdriver, a credit card to force open a door, or a hanger to break into our locked car (not someone else's, let us hope, and surely not, let us pray, for ending unwanted pregnancies in our newly dawning era of restrictions). And any vital function narrowly restricted to one organ gives a lineage little prospect for long-term evolutionary persistence; redundancy itself should possess an enormous advantage. (Redundancy in this form solves the otherwise intractable problem of evolution in mammalian jaws, as outlined above. Intermediary forms, as shown by direct evidence of fossils, not abstract conjecture, developed a second articulation between dentary and squamosal bones [the current mammalian jaw joint] while elements of the old articulation could lose their former function and pass into the ear.)

In fact, the swim bladder itself provides an excellent example of multiple possibilities as a norm. The swim bladder is primarily an organ of buoyancy in teleost fishes. By filling the bladder with gas, an animal that would otherwise sink becomes neutrally buoyant and can rest without expending energy in the midst of the water column. (In a related function, fishes at neutral buoyancy gain more power in forward motion because they need not divert energy into supplying lift to counteract sinking—see R. McNeill Alexander's "Physical Aspects of Swim Bladder Function," *Biological Reviews,* volume 41, pages 141–76.) Interestingly, some sharks are pelagic (floating) in habit; how can they stay up, since their entire lineage lost the organ that becomes a lung or swim bladder in other fishes? These sharks have enormous livers constructed largely of a hydrocarbon with a density considerably less than seawater—another good example of multiple use as a norm.

But the swim bladder performs at least three other important but secondary functions in many species of teleost fishes:

(1) Most curiously, perhaps, the swim bladder has reacquired a supplementary respiratory function in several lineages of fishes, all living in swampy or stagnant waters, where gulping air at the surface might be an important alternative to breathing with gills.

(2) Many teleosts use their swim bladder as an organ of sensation. Since gas is so responsive to changes in pressure, some fishes can judge their depth in the water column with receptors embedded in the wall of their swim bladder. Many other fishes use their swim bladder as an accessory organ of hearing. Gases are more compressible than water, and sound vibrations may be recorded more sensitively in their impact upon swim bladder gases than upon any other part of the body. Supplementary hearing has evolved in at least two strikingly different ways. Some fishes have developed thin forward extensions of the swim bladder; these pass through openings of the skull and make direct contact with the ear. In another major group, the cypriniforms (including most of the world's freshwater fishes), vibrations from the swim bladder are transmitted to the ear via a chain of three separate bones located on either side of the vertebral column and called Weberian ossicles to honor the German scientist who recognized their mode of operation in 1820. (Darwin used this example of multiple function in the *Origin of Species*.)

(3) Sound production. Again, several lineages use the swim bladder either to enhance sounds made by other parts of the body or as a direct agent of production. (Some fishes are essentially silent, but many make sounds, especially in courtship or in aggressive displays.) The triggerfish *Balistes* (another lovely name) stridulates by rubbing its postclavicle bone against its cleithrum—but this otherwise minor sound is greatly amplified by resonance from the adjacent swim bladder. Another group of fishes grates its pharyngeal teeth, and also turns a little rumble into a modest roar by resonance of the swim bladder. In other fishes, the swim bladder produces sounds directly by expulsion of gas bubbles. T. H. Huxley once wrote a special note to *Nature* (in 1881) to describe what can only be called herring farts. These fish expel gas in pulses from the swim bladder out an orifice adjacent to the anus. In the oh-so-proper style of scientific reporting, a British review article of 1953 described Huxley's suggestion "that the mouse-like squeaks made by captured herring might

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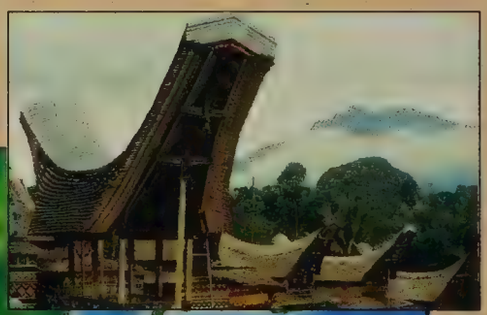

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be caused by the escape of gas through the posterior opening."

If I may move, in conclusion, from minor end rumblings to a renewed assault upon the high ground, I don't know if the *Origin of Species* contains an argument more general or more important than Darwin's recognition that pervasive redundancy makes evolution possible. If animals were ideally honed, with each part doing one thing perfectly, then evolution would not occur, for nothing could change (without losing vital function in the transition), and life would quickly end as environments altered and organisms did not respond.

But rules of structure, deeper than natural selection itself, guarantee that complex features must bristle with multiple possibilities—and evolution wins its required flexibility thanks to messiness, redundancy, and lack of perfect fit. Human creativity is no different, for I think we are dealing with a statement about the very nature of organization—something so general that it must apply to any particular instance.

How sad then that we live in a culture almost dedicated to wiping out the leisure of ambiguity and the creative joy of redundancy. These days, even the most complex concepts must be reduced to photo opportunities and sound bites, and elections are decided by fifteen-second images of men surrounded by flags, and alleged criminals walking through symbolic revolving doors. We may be creating a generation of sheep—and although these pleasant mammals outnumber New Zealanders by almost twenty-five to one, I rather suspect that *Homo sapiens*, properly nurtured by redundancy and ambiguity, will continue to prevail.

Redundancy, and its counterpart of ambiguity in multiple meaning, are our way, our most precious, most human way. We rail at computers because for all their awesome power, they do not grasp our essential ambiguities. They cannot adequately translate one of our languages into another, and we must speak to them in a way utterly unnatural for us—that is, without ambiguity (hence an entire industry devoted to debugging). Faced with La Guardia's or Darwin's errors, they grind to a halt. We adjust, we parry, we prevail, we transcend. It could be one hell of a partnership, so long as we keep the upper hand. I shall place my bets on the shepherds of New Zealand and hope that the analogy holds.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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Gray squirrels chase each other incessantly, sometimes in play, often in disputes over food, sex, or caching sites.
Alan Carey

Cache Economy of the Gray Squirrel

For nine months of the year, this squirrel survives by dipping into its savings

by Lucia Jacobs

With its ancient trees, the Princeton University campus is a good place for squirrels. Every April and May, gray squirrel babies seem to rain to the ground, where they are sometimes "rescued" by students. Attempts to care for the little rodents in a dormitory usually result in a call for help to the biology department.

With a curiosity about squirrels, and a doctorate to complete, I seized this opportunity to study the gray squirrel's most endearing trait: burying nuts. Every spring my apartment slowly filled with boxes of baby squirrels. These home-reared animals, fed on milk and soft foods until adolescence, faced their first nut without any previous exposure to the problem. I hoped to discover whether their lack of experience would hinder them in any way.

The squirrels performed flawlessly from the first day. I was fascinated as I observed one of these miniature squirrels pick up a hazelnut for the first time, search intently for a suitable burying site, and then, with great zest, dig a hole, both paws flying, the nut firmly clenched between tiny teeth, with all the apparent confidence and success of a jaded park squirrel burying its millionth peanut.

Why do all gray squirrels, even these pampered orphans, hide each nut in a separate hole? And do they remember where they have stored their nuts?

My initial survey of the scientific literature revealed that this familiar mammal's behavior had not been studied as much as that of the lion or the elephant. Nearly everyone has seen a gray squirrel storing nuts, yet when I began my research, there were few formal studies of this behavior, none conducted under completely natural conditions. The squirrel literature did, however, contain one revelation about gray squirrels that later proved quite relevant to my research: the vast migrations of gray squirrels recorded in earlier centuries. In the eighteenth and nineteenth centuries, travelers in North America reported seeing armies of squirrels, sometimes numbering in the thousands, making their way across fields, forests, and rivers. These movements continued to amaze and appall the citizenry until the squirrels' habitat, deciduous forest, was greatly reduced in the late 1800s.

W. N. Blane, in *An Excursion through the United States and Canada during the Years 1822–1823* (1824), wrote an account of such a migration:

> I could scarcely believe my eyes, when I saw the immense number of these animals. . . . I found that this host of squirrels had in many places destroyed the whole crop, and that the little fellows were sometimes seen, three or four upon a stalk, fighting for the ear. One party of hunters, in the course of a week, killed upwards of 19,000. In most places, however, there were such multitudes of them, that the inhabitants quite despaired of being able to rid themselves of this plague.

Other species, such as fox squirrels, red squirrels, and chipmunks, might have joined these hordes, but the gray squirrels were the most numerous by far. John James Audubon was so struck by the squirrels' wanderlust that he gave the name "migrating squirrel," or *Sciurus migratorius,* to what he thought was a separate species but which turned out to be another gray.

The gray squirrels' migrations were undoubtedly a response to changes in their food supply. The species evolved in a virtual ocean of food trees—the primeval deciduous forest that once covered the North American continent from the Atlantic Ocean to the Mississippi River. The annual changes in the squirrels' diet must have been much the same then as they are now. In the spring, squirrels eat tree buds, tree flowers, and early seeds, such as maple samaras. These provide energy and key nutrients, such as calcium and sodium (the need for which may explain ghoulish reports of squirrels nibbling tombstones). In June and July, squirrels add mulberries, black cherries, and other fruits to their menu. But by midsummer, food is scarce, and by late July, the squirrels lose weight, resorting to such inferior foods as mushrooms. With the coming of fall, however, the mainstay of the squirrels' diet—acorns and other nuts—appears.

But even when the forests were at their most extensive, and oaks and hickories in seemingly endless supply, the fall harvest

Plump from weeks of feasting on nuts and acorns, a squirrel buries one of the many nuts that will have to sustain it in the leaner times to come.
Tom A. Schneider

was unpredictable. Oaks and hickories produce huge crops of acorns and nuts, but only at odd intervals. During some autumns, often those following a late spring frost, which may kill the trees' flowers, there is virtually no seed crop at all. Compiling information from newspapers and travelers' accounts, A. W. Schorger showed how squirrel migrations correlated with years of poor seed production. His work, published in 1949, showed that other species were also affected by the trees' crop failure; in acorn-poor years, for example, newspapers reported free-running hogs starving to death in the forest.

Innumerable changes in the North American landscape eventually brought an end to the great squirrel migrations, although an occasional small exodus has been observed in the twentieth century. The gray squirrel is still, however, very much affected by fluctuations in nut crops. This species is the most fecund of tree squirrels, but as Charles Nixon and his colleagues at the Illinois Natural History Survey have shown, a female gray squirrel's reproductive output is highly variable and directly correlated with the number of nuts produced on her home range in a given year. This correlation is a result of both a squirrel's dependence on stored food (for up to nine out of every twelve months) and the limited time the food can be stored.

As a rule, tree squirrels keep alive from fall until spring by eating stored foods, while ground squirrels hibernate. (Some squirrels, such as the eastern chipmunk, do both.) But some tree squirrels have an easier time of it than others. Those that live in evergreen forests, such as the red squirrel of eastern and northern forests and the chickaree of western forests, generally gather pine cones and hoard them near their nests. Such pine cones may not be abundant every year, but if cut green and stored in a moist spot, they may last several years. But gray and fox squirrels must replace their stored food supplies every year, for acorns and nuts germinate the same year they are buried. When trees fail to produce many nuts, these squirrels' reproductive success, as well as survival itself, is jeopardized.

Given the gray squirrel's life-and-death dependence on stored food, its manner of storing may seem oddly inefficient. Most food-storing mammals maintain either a single larder or a mix of central larder and many spread-out, smaller caches. Eastern chipmunks, for example, keep a large underground store in their burrows and, as this is depleted, turn to scattered surface stores to replenish it. The gray squirrel's habit of burying each nut separately—called scatter-hoarding—seems cumbersome. Why does this squirrel avoid putting all its "eggs" in one basket?

Christopher Smith, of the University of Kansas, has suggested that the distribution of nuts and acorns and competition from other seed eaters force gray squirrels to scatter-hoard. Because gray squirrels may not know which trees will produce a big crop, the argument goes, each squirrel must forage over a large area each year. (A "large area," in this context, does not mean the hundreds of miles traversed by migrating squirrels in search of food. The contemporary gray squirrel is relatively sedentary, spending its entire five- to six-year life span on a few acres.) Such a large area cannot be exclusive, as other squirrels inevitably arrive to harvest seeds from the masting trees. For that matter, even small areas cannot be defended against an influx of competing squirrels, so the only chance is to cover a lot of territory.

Support for this theory comes from Hélène Lair, of the University of Laval, who observed red squirrels in Quebec and found that they put food in larders only when it was abundant and easily harvested from an area small enough to be subsequently defended. Otherwise they acted like gray squirrels, scattering many small, hidden, undefended caches.

All of this suggested that if I wanted to understand caching in gray squirrels, I would need to find out how the squirrels' food was distributed and how they foraged for it. My field site was the woods adjoining the Institute for Advanced Study in Princeton, New Jersey. This continuous tract of woodland is far from primeval, but the fifteen-acre section I chose for my study site is at least one hundred years old. The Institute woods themselves are large enough (162 acres) to assure that my study animals were residents of the woods, not artificially provisioned squirrels from the surrounding suburbs. The composition of the site varied from almost pure oak-hickory stands at the northern limit of the site to beech, white pine, and sweet gum at the southern end.

My plan was to catch and mark all the gray squirrels on the site and then follow them during the fall harvest as they foraged for nuts to eat and to cache. To get the clearest possible picture of what was going on, I decided to focus on hickory trees. For one thing, in my area at least, hickory nuts are eaten almost exclusively by gray squirrels, so I could pretty much rule out competition from other seed eaters as a reason for scatter-hoarding. To be absolutely sure, I studied a booklet written by Ward Sharp, of Pennsylvania State University, describing the remains of nuts and acorns after various rodents have extracted their fill. Gray squirrels use their jaws like a crowbar: they insert their lower incisors into a hole they have gnawed and snap off chunks of hickory shell, bit by bit, exposing the meat inside. With this method, they can empty a rock-hard hickory nut in minutes.

Small squirrels don't have the jaw strength for this maneuver, so they laboriously gnaw a hole in one side of the nut, enlarging it slowly as they clean out the nutmeat it exposes. Baby gray squirrels start their hole near the top of the nut, red squirrels make one hole on each side to get at the kernel, and flying squirrels and chipmunks clean nuts the way we clean pumpkins, by removing the top third of the nut and scooping out the insides. Poring over some 3,000 to 4,000 chewed hickory nuts that I collected convinced me that gray squirrels were indeed the main hickory nut predators in my woods.

Another reason for focusing on hickory nuts was that they were clearly the gray squirrel's favorite. Fall presented the squirrels with a smorgasbord of acorns, from black, red, and pin oaks, and nuts from the three species of hickories, shagbark, sweet pignut, and mockernut, but the squirrels consistently chose hickories first. Furthermore, they showed definite

preferences for certain trees. For three years in a row, the squirrels began the fall harvest in a particular shagbark. At this early stage of the harvest, they totally ignored the oaks, although once the hickory nuts were almost gone, they did eat and cache quite a few acorns.

Stephen Havera, also with the Illinois Natural History Survey, has shown that a hickory nut has almost twice the calories of an average acorn, so it is no surprise that squirrels eat hickory nuts first. But shagbark nuts and mockernuts have almost the same nutritional content, so why eat shagbark nuts first? To answer this question, I calculated a crude measure of a nut's value by dividing its diameter by the thickness of its shell. In terms of calories gained and energy expended, a large nut protected by a thick shell might be equal in value to a smaller nut with a thin shell. This ratio varied significantly not only between species but also between individual trees of the same species. For example, shagbark nuts are large with relatively thin shells; mockernuts are even larger but have very thick shells; sweet pignuts are small and thin shelled. But among shagbark hickories, some trees produced larger, thinner-shelled nuts than others, and squirrels spent a disproportionate amount of time in these trees. Once the very best trees were depleted, the squirrels turned to others, mostly shagbarks but also some of the more numerous mockernut hickories and a few of the relatively rare sweet pignut hickories.

So I had a fairly simple system to study: one species of squirrel and three species of hickory. After numbering each individual tree, mapping its location, and estimating its nut crop (by counting nuts in sample parts of the visible tree canopy), I needed some squirrels. I baited wire traps, putting peanut butter on the treadle and sprinkling a trail of sunflower seeds leading into the trap. During three field seasons, I caught and tagged eighty different squirrels on my site. In the second and third years of my study, eight to twelve adults each year also received a homemade radio transmitter, which allowed me to pinpoint a squirrel's whereabouts.

Once the trees and the animals were marked, the squirrels and I waited for the nuts to ripen. When they did, the feasting began. During the early days of the harvest, preferred trees swarmed with squirrels. By the end of September, as the squirrels spread out, the number of squir-

John R. Patton

Squirrels use smell and, especially when the snow is deep, memory to locate stored food. The squirrel at left, successful in its search, dashes away to eat its prize on a safe perch. Come spring, squirrels eat the buds and flowers of horse chestnuts, below, and other trees.

E.A. Janes; Nature Photographers Ltd.

rels feeding in any particular tree had dropped to only one or two.

Trees were not stripped completely, for squirrels are choosy eaters, picking their way carefully along branches, sniffing daintily at each nut, detaching some and leaving others untouched. If a squirrel plans to eat a nut, it generally does so then and there, growling at any other squirrel that tries to pass it on the branch. I also observed young squirrels jump to a neighboring, nonfood tree to eat, perhaps to avoid harassment by adults.

At times, the squirrels seemed constantly on the move. Most of the oak-hickory stands were in the northern section of the woods, so the hub of activity was there, but trees with good nuts were sought out no matter where they were. Even at the peak of the nut harvest, however, squirrels must rest sometime. They build nests, sometimes in tree cavities, sometimes just a hollow ball of leaves. The distance over which a squirrel had to travel from its nest to the current food supply changed weekly as the nuts on different trees ripened, but in general, squirrels nesting in the south had the longest commutes. The longest distance any of my radio-tagged squirrels traveled from nest to food was 250 yards. At this distance, commuters made only two round trips a day. Some "northern" squirrels, in contrast, lived only 20 yards from the most preferred food trees.

At my study site, all radio-tagged squirrels had moved to new wintering nests by mid-September, halfway through the fall harvest. Squirrels already living in the productive north moved less than fifty yards, whereas individuals living in the south moved several hundred yards in the direction of food trees.

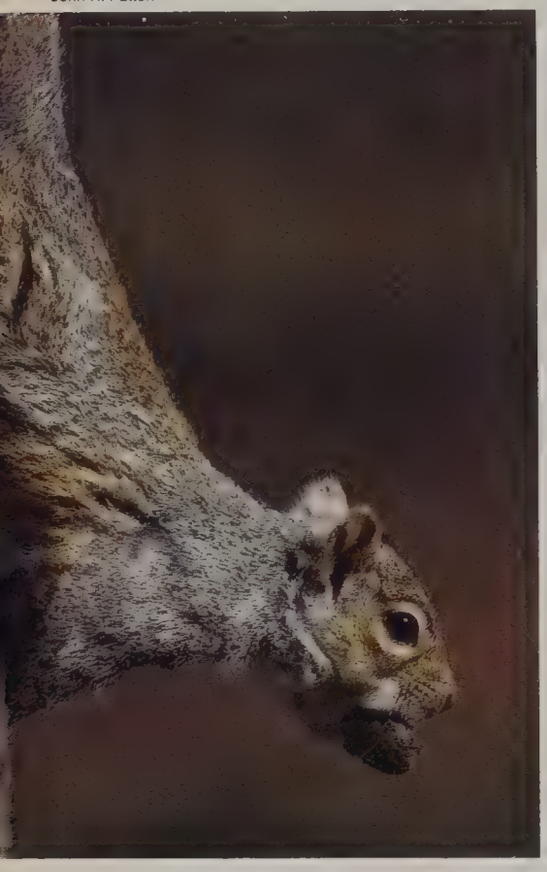
As the fall progressed and large, thin-shelled nuts gave way to large, thick-shelled nuts, the squirrels stepped up the proportion of nuts they buried. A squirrel intent on burying a nut usually carries it, unhusked, to the ground, holding it by the stem. Once on the ground, the squirrel starts hopping quickly in the direction of home. Often it disappears under a bush or brier and reappears shortly without a nut. Since gray squirrels always eat noisy items like nuts in exposed places, where they can keep a lookout for predators, such as red-tailed hawks, I assumed such disappearances had resulted in a cache.

Caching behavior is highly stereotyped and, in my experience, the same in any setting. After finding a general area acceptable for caching, the squirrel slowly hops around, sniffing various spots before making its decision, perhaps based on moisture. If the ground is too wet, the nut may rot; if it's too dry, the squirrel may have trouble sniffing out the nut again.

Before interring a hickory nut, a squirrel always removes its fragrant husk. This may reduce the risk of discovery by a competitor. One sign of the caching season, in fact, is the appearance of small piles of green husk chips on the ground in September. After husking the nut, the

Resting on its haunches, a curious squirrel pauses in its search for food in spring.
Frank W. Mantlik

Even in springtime, squirrels continue to turn to their caches. This squirrel, thin and scruffy at winter's end, has just unearthed a hickory nut, one of its favorite and most nutritious foods.
John R. Patton



squirrel digs a hole, one to two inches deep, using its front paws alternately. After the hole is dug, the nut is laid in it and then rammed firmly in place, the squirrel hitting the nut with its front teeth and putting its entire body behind the movement. Then the squirrel covers the nut with dirt and then, moving more slowly, with ground litter. They often show great care, replacing dead leaves one at a time, in an apparent effort to disguise their buried treasure. I observed similar behavior in captive animals. A captive squirrel that had just finished "caching" a nut in a corner formed by two walls and a bare floor would slowly wave its paws over the nut, which was sitting in plain sight.

One interesting finding that came out of my work in the woods was that squirrels would tolerate certain others caching nuts in the one- to two-acre areas near their nesting trees. I was surprised at this, since the species is generally described as asocial. Some of these squirrels also spent the winter in the same nest. One group, living in the midst of the most popular hickory trees, cached and nested together for all three years of my study. The group was composed of an adult female, an adult male (possibly mother and son), and subadults, both male and female. Most of the subadults disappeared after one year, but one of the young females remained on the site, raising her own litter in a nest less than fifty yards away.

Perhaps, then, squirrels that cache near one another are related. Caching with kin may reduce some of the harm done if a nut is dug up and eaten by another squirrel. Chances are that the robber will be a relative, so the purloined nut will at least be benefiting the survival of an individual with some of the same genes. But a squirrel's decision on where to cache is more complicated than whether to go it alone or with others and involves just how valuable the load is. Bigger loads, such as two hickory nuts joined by a stem, are stashed farther from the food source than smaller ones. This "rule" held for squirrels I observed both in the wild and on the Princeton campus, where I experimentally glued hazelnuts together, and has also been demonstrated in fox and red squirrels.

Fundamental to the whole strategy of caching and retrieval is the question of memory: Can a gray squirrel remember where it buries its food? This question had been tossed around in the literature since 1884 but had not been addressed experimentally. This was partly because biologist Victor Cahalane, while at the University of Michigan, showed in 1942 that fox squirrels could find almost all the nuts that the experimenter had buried. Most researchers concluded that the squirrels located the nuts by smell and that they thus didn't have to remember its location. Public opinion on the subject was summed up by Will Cuppy in his 1949 book, *How to Attract the Wombat:* "Squirrels have been criticized for hiding nuts in various places for future use and then forgetting the place. Well, squirrels do not bother with minor details like that. They have other things on their mind, such as hiding more nuts where they can't find them."

To address the question of squirrel memory, I observed hand-reared squirrels caching and retrieving nuts in a five-by-ten-yard outdoor arena. Each squirrel was released alone into the empty arena and allowed to bury ten hazelnuts. The squirrel was then returned to its cage, where it stayed for from two to twelve days before being released again into the arena to retrieve its buried nuts. But in the meantime, I had removed its nuts and put ten fresh ones in their place. In addition, I put ten more fresh nuts in sites chosen randomly from a list of sites that other squirrels had chosen during that week. In this way, I hoped to simulate the situation faced under natural conditions, where a gray squirrel potentially has a choice of two types of caches—its own and its neighbors'. I found that despite an equal number of both cache types being available, each squirrel retrieved significantly more nuts from sites it had chosen than from the other squirrels' hiding places. The task the captive squirrels faced was, of course, much easier than that faced by wild squirrels caching many more nuts over a much greater area and retrieving them many weeks later, but the experiment did show that gray squirrels can rely on memory to relocate caches.

Spatial memory has been demonstrated in food-storing birds, such as the black-capped chickadee and the Clark's nutcracker (see *Natural History,* September 1983). Memory in mammalian food storers, which can also sniff out caches, probably functions differently from memory in birds, which generally lack this olfactory ability. For a gray squirrel, the ability to remember where it buried food may only be important when the ground is covered with deep snow and trial-and-error searching is too costly. Even a few weeks of heavy snow each winter may produce a sufficient selective pressure to maintain the gray squirrel's memory.

Nevertheless, it will no doubt be a while before the populace is convinced that gray squirrels' cerebral capacities are worthy of respect. As Will Cuppy put it: "The squirrel is out for a good time. He rushes through the treetops, plays tag with the other squirrels, eats all the nuts he can hold, and generally behaves as though the world was made for that sort of thing. He is so glad to be alive that nobody has any respect for his mental powers." □

Strong, light, flexible, and widespread in Asia, bamboo, below, may have been crucial to the development of human culture in that region. Inset: Chinese workers use bamboo poles to transport a heavy stone.
Dana Levy

Bamboo and Human Evolution

In Asia, a giant grass may have shaped the course of prehistoric technology for more than one million years

by Geoffrey G. Pope

Today the seven-mile journey from the highway to our field camp in the Wang Valley seems almost too easy. In the ten years since I began paleoanthropological work in northern Thailand, roads have replaced bullock paths, and sugar cane fields lie where dense teak stands once towered. Taking only minutes to pass through the local village, our *song-tao,* or "two-bench" pickup truck, is well on the way to Kao Pah Nam (Wild Thorn Hill), a craggy spine of limestone clothed in treacherous thorn scrub. Everybody in the *song-tao* knows enough to lean into the center of the vehicle to avoid the razor-sharp thorns that rake the open sides.

Reaching our destination, we file out, impatient to flex cramped limbs, shake off the layers of cold dust, and rub new bruises. We are standing at the base of a karst ridge. Karst (first named for the Karst region of Yugoslavia) is an irregular terrain that develops when ground water saturated with carbonic acid erodes limestone. In tropical forests the effects are particularly striking because the dense root systems and thick layers of decaying organic matter give off a great deal of carbon dioxide, which in combination with water forms carbonic acid. All around us are imposing pinnacles with intriguing fissures and caves. For the paleoanthropologist, karst is especially inviting since caves attract animals seeking shelter, and early hominids—human ancestors and their relatives—would have been no exception. The caves trap bones and cement them in a limestone breccia, preserving fossils that would otherwise disintegrate on the tropical forest floor, with its acid soil and its active insect and microorganic life.

In prehistoric times the karst environment would have provided attractive resources for early humans. Today people still seek out caves during the hot dry season for their shaded, cool, subterranean waters. Bats, birds, snakes, and small mammals that live there are routinely collected for food. Karst towers also provide convenient points from which to survey the surrounding countryside and are important in the rainy season, when most rivers flood and the lowland country becomes inundated for months at a time. The limestone is also mined for phosphates, quicklime, and building stone.

From the forest around us comes the complacent, comforting cooing of "forest chickens." Suddenly, a series of explosions silences the birds. Some of the reports are as loud as dynamite blasts, but local inhabitants take no notice. For them the explosions are as natural as the sounds of the forest animals. They emanate from an unseen grove of bamboo that some villagers have set alight; the crackling sound of a brush fire accompanies them. The air in the sealed bases of the hollow bamboo trunks expands until they blow apart, felling the giant stalks (the word *bamboo* is Malay in origin and thought to be onomatopoeic for these explosions). This is the first step in the harvesting of a versatile raw material. For me, the explosions are fascinating, because I suspect that these same sounds have echoed in this valley for a million years, and that bamboo has shaped the course of human evolution in this part of the world.

Bamboo provides, I believe, the solution to a puzzle first raised in 1943, when the late archeologist Hallam Movius of Harvard began to publish his observations on paleolithic (Old Stone Age) cultures of the Far East. In 1937 and 1938 Movius

Wolfgang Kaehler

Full of sinkholes and caves, karst hills like these in a tropical forest in northern Thailand contain evidence of prehistoric human activity.
Geoffrey G. Pope

AMNH

Joe LeMonnier

Prehistoric tools made in eastern and southeastern Asia, right, are less standardized than those—such as the Acheulean hand ax, above—fashioned elsewhere in the Old World during the same period. A distinct boundary between the two types (see map) was delineated more than forty years ago by archeologist Hallam Movius. Since then, new finds have begun to fill in our knowledge of toolmaking in northern Asia. The distribution of the Asian tools corresponds closely to the natural range of bamboo.

Jia Lanpo; *Early Man in China*

had investigated a number of archeological localities in India, Southeast Asia, and China. Although most of the archeological "cultures" that he recognized are no longer accepted by modern workers, he made another, more lasting contribution. This was the identification of the "Movius line" (which his colleague Carleton Coon named in his honor): a geographical boundary, extending through northern India, that separates two long-lasting paleolithic cultures. West of the line are found collections of tools with a high percentage of symmetrical and consistently proportioned hand axes (these are called Acheulean tools, after the French site of Saint Acheul). More or less similar tool kits also occur in Mongolia and Siberia, but with few exceptions (which are generally relatively late in time), not in eastern China or Southeast Asia, where more crudely made tools known as choppers and chopping tools prevail.

Although both types of tools are attributed to our hominid ancestor *Homo erectus* and are of similar age (Acheulean tools are from 1.5 million to 200,000 years old; chopper-chopping tools from 1 million to 200,000 years old), Acheulean tools have long been regarded as more advanced than the more crudely made and less standardized tools of the Far East, which some have called a smash-and-grab technology. Movius was among the first to ponder the significance of this geographical division. In 1948 he published his conclusion that the Far East was a region of "cultural retardation," which he believed could never have

> played a vital and dynamic role in early human evolution, although very primitive forms of Early Man apparently persisted there long after types at a comparable stage of physical evolution had become extinct elsewhere.

For years this explanation was accepted and even, in the interpretations of Carleton Coon and others, taken as evidence of racial isolation and backwardness.

With the flowering of the civil rights movement in the 1960s, most anthropologists rejected the notion of cultural retardation, especially if it had racial overtones. Now some suggest that *all* early human ancestors (not just the Asian hominids) had minimal capacities for culture, that is, for toolmaking and other types of socially learned behavior. Lewis Binford, of the University of New Mexico, has been influential in this view. He has spent the last few years reexamining evidence from a number of archeological localities and has concluded that many characterizations of past cultural behavior are based on very little solid data. At any rate, Binford and others would attribute the crudeness of the artifacts from China to the general inability of early hominids to manufacture standardized stone tools.

The problem with this is that it doesn't really solve the mystery of the Movius line. Over the years, however, a few archeologists have put forward a very different line of reasoning, which I have found to be more fruitful. Their idea is that the early Asians may have relied heavily on tools that they made from raw materials

other than stone, and since these are seldom preserved at archeological sites, we simply lack a balanced appreciation of their accomplishments. This suggestion has not generally been pursued, primarily because it is hard to confirm—after all, there is not much use in going out to dig for what probably has not been preserved.

One promising method of detecting nonlithic technology is to study the cut marks on fossil bones. Jolee West, a graduate student at the University of Illinois, has been experimenting with using the electron microscope to differentiate between the kinds of damage left by stone and other cutting implements. Continued development of this approach should eventually offer a direct means to test for the prehistoric use of nonlithic tools.

My own research on the Movius line and related questions evolved almost by accident. During the course of my work in Southeast Asia, I excavated many sites, studied a variety of fossil faunal collections, and reviewed the scientific literature dealing with Asia. As part of this research I compared fossil mammals from Asia with those recovered from other parts of the world. In the beginning, my purpose was biostratigraphic—to use the animals to estimate the most likely dates of various sites used by early hominids. On the basis of the associated fauna, for example, I estimate that Kao Pah Nam may be as old as 700,000 years.

After years of looking at fossil collections and faunal lists, I realized that something was very strange about the collections from Southeast Asia: there were no fossil horses of Pleistocene age (1.6 million to 12,000 years ago) or for a considerable time before that. The only exceptions were a few horse fossils from one place in southern China, the Yuanmou Basin, which was and is a special small grassland habitat in a low, dry valley within the Shan-Yunnan Massif.

To mammalian biostratigraphers this is unusual, since members of the horse family are so common in both the Old and New World that they are a primary means of dating various fossil localities. Fossil horses have been reported from western Burma, but the last one probably lived there some twenty million years ago. Not a single fossil horse turns up later than that in Southeast Asia, although they are known from India to the west and China to the north and every other part of Europe and Asia.

I then began to wonder what other normally common animals might be missing. The answer soon became apparent: cam-

Bamboo is split for a Chinese pulp mill

Piglets in a bamboo basket, Thailand

Both photographs by Wolfgang Kaehler

els—even though they too were once widespread throughout the world—and members and relatives of the giraffe family. Pleistocene Southeast Asia was shaping up as a kind of "black hole" for certain fossil mammals! These animals—horses, camels, and giraffids—all dwell in open country. Their absence on the Southeast Asian mainland and islands (all once connected, along with the now inundated Sunda Shelf) is indicative of a forested environment. The mammals that are present—orangutans, tapirs, and gibbons—confirm this conclusion.

The significance of this is that most reconstructions of our evolutionary past have emphasized the influence of savanna grassland habitats, so important in Africa, the cradle of hominid evolution. Many anthropologists theorize that shrinking forests and spreading grasslands encouraged our primarily tree-dwelling ancestors to adapt to ground-dwelling conditions, giving rise to the unique bipedal gait that is the hallmark of hominids. Bipedalism, in turn, freed the hands for tool use and ultimately led to the evolution of a large-brained, cultural animal. Tropical Asia, instead, apparently was where early hominids had to readapt to tropical forest.

In studying the record, I noticed that the forested zone—the zone that lacked open-dwelling mammals—coincided generally with the distribution of the chopper-chopping tools. The latter appeared to be the products of a forest adaptation that, for one reason or another, deemphasized the utilization of standardized stone tools. At least this held for Southeast Asia; what at first I could not explain was the existence of similar tools in northern China, where fossil horses, camels, and giraffids were present. Finally, I came upon the arresting fact that the distribution of naturally occurring bamboo coincided almost perfectly with the distribution of chopper-chopping tools. The only exceptions that may possibly be of real antiquity—certain hand ax collections from Kehe and Dingcun, in China, and Chonggok-Ni, in Korea—fall on the northernmost periphery of the distribution of bamboo and probably can be attributed to fluctuation of the boundary.

Today there are, by various estimates, some 1,000 to 1,200 species of bamboo. This giant grass is distributed worldwide, but more than 60 percent of the species are from Asia. Only 16 percent occur in Africa, and those on the Indian subcontinent—to an unknown extent the product of human importation and cultivation—are discontinuous in distribution and low in diversity. By far, the greatest diversity occurs in East and Southeast Asia.

Based on these observations, I hypothesized that the early Asians relied on bamboo for much of their technology. At first I envisioned bamboo simply as a kind of icon representing all nonlithic technology. I now think bamboo specifically must have been an extremely important resource. This was not, in my opinion, because appropriate rock was scarce but because bamboo tools would have been efficient, durable, and highly portable.

There are few useful tools that cannot be constructed from bamboo. Cooking and storage containers, knives, spears, heavy and light projectile points, elaborate traps, rope, fasteners, clothing, and even entire villages can be manufactured from bamboo. In addition to the stalks, which are a source of raw material for the manufacture of a variety of artifacts, the seeds and shoots of many species can be eaten. In historical times, bamboo has been to Asian civilization what the olive tree was to the Greeks. In the great cities of the Far East, bamboo is still the preferred choice for the scaffolding used in the construction of skyscrapers. This incomparable resource is also highly renewable. One can actually hear some varieties growing, at more than one foot per day.

Some may question how bamboo tools would have been sufficient for killing and processing large and medium-size animals. Lethal projectile and stabbing implements can in fact be fashioned from bamboo, but their importance may be exaggerated. Large game accounts for a relatively small proportion of the diet of many modern hunters and gatherers. Furthermore, animals are frequently trapped, collected, killed, and then thrown on a fire

Umbrellas with bamboo struts and ribs, Thailand
Paul Slaughter; The Image Bank

Sumatran farmer, water buffalo, and a plow supported by bamboo poles
Wolfgang Kaehler

and cooked whole prior to using bare hands to dismember the roasted carcass. There are many ethnographic examples among forest peoples of this practice.

The only implements that cannot be manufactured from bamboo are axes or choppers suitable for the working of hard woods. More than a few archeologists have suggested that the stone choppers and resultant "waste" flakes of Asia were created with the objective of using them to manufacture and maintain nonlithic tools. Bamboo can be easily worked with stone flakes resulting from the manufacture of choppers (many choppers may have been a throwaway component in the manufacture of flakes).

In addition to bamboo, other highly versatile resources such as liana, rattan, and various reeds are also found in Asian forests. To really appreciate the wealth of resources one has to visit Southeast Asia today. Even though many forested areas have been disturbed or even destroyed by humans, those that remain offer an accurate picture of the variety of habitats that early hominids encountered when they first reached the Far East. Southeast Asia is dominated by tropical forest, but this is not necessarily rain forest. While evergreen rain forest exists in Indonesia, the monsoon forest in northern Thailand is deciduous. In northern China there is boreal woodland forest.

Most of my work has been in northern Thailand where the forests are burned every year, frequently not for agricultural reasons but to permit the passage of human foot traffic. Despite burning during the dry season (January–April), the forests are once again impenetrable at the end of the wet season (September–December). Many of the hardwood trees, such as the various kinds of teak, are fire resistant and seem little affected by these seasonal conflagrations, indicating that fire played an important role in their evo-

lution. This may be evidence that fire, first used by our ancestors in tropical Africa, aided the colonization of the Asian forests by *Homo erectus*. Fire would also have been instrumental in the working and utilization of nonlithic resources such as bamboo. This relationship between humans, fire, and the forest is probably more than one million years old in Asia.

Our thorn-bedecked site of Kao Pah Nam, where we have been excavating a rock-shelter (shallow cave), itself preserves evidence of fire. Here we have discovered a roughly circular arrangement of fire-cracked basalt cobbles, in association with other artifacts and animal bones. These hearth stones had to have been brought in by early hominids, as very few nonlimestone rocks lie in the rock-shelter. At first I wondered why our early ancestors would have bothered to lug these heavy rocks into their shelter when limestone was abundant at the site.

The answer emerged as the result of a sort of accident in our field camp. For a number of days we had been cooking our meals on a hearth made of local limestone. A few days into the field season we began to notice that people were complaining of itchy and burning skin rashes. The symptoms were very unpleasant. At first we assumed the cause to be some sort of malevolent plant or fungus. By this time camp life had become uncomfortable and there were further complaints of shortness of breath and burning lungs. Finally, one

A painter climbs bamboo scaffolding outside a modern building in Hong Kong. Inset: Strong and durable, woven bamboo is the material used for a house wall in Maymyo, Burma.
Robert Harding Picture Library

of our Thai workers pointed out that the rocks of our cooking hearth, after numerous heatings and coolings from our fires, had begun to turn to quicklime. The heat, in conjunction with water from numerous spilled pots of soup and boiling kettles of coffee, had caused this caustic substance to become distributed throughout the dusty camp. We quickly replaced the limestone rocks with ones made of basalt. Only months later did it dawn on me that the early hominids that lived at Kao Pah Nam also must have known about the dangers of cooking on limestone. This explained why they bothered to bring in nonnative rocks.

On the basis of our ongoing excavations we have concluded that Kao Pah Nam was occupied intermittently by both carnivores and hominids. Bones of extinct hyenas, tigers, and other carnivores are confined primarily to the deeper recesses of the rock-shelter, likely to have been preferred by denning animals. The hearth and other artifacts, on the other hand, are located near what was the entrance. Many of the prey animals that have been recovered are large by modern standards and include hippo and giant forms of ox, deer, bamboo rat, and porcupine. Nothing about the animals suggests anything but a forested environment.

Artificial cut marks (as well as gnaw marks of large porcupines) are present on the bones associated with the hearth and artifacts. Bones that apparently had been burned have also been recovered. Other evidence that bears on the diet of early hominids consists of extinct freshwater oyster shells piled on top of one another against the rock-shelter wall. This area remains to be fully excavated.

As the result of our work at Kao Pah Nam and other early Pleistocene sites in Thailand, we are beginning to put together a picture of regional artifact types, frequency, and age. There appears to be a simple but systematic pattern of manufacturing choppers and other artifacts by removing a few flakes from one side of a lump of stone. A similar pattern is turning up in karst caves in southern China. In all these sites, small flakes are absent or rare. One interpretation is that the flakes were carried off into the forest for use in processing raw materials.

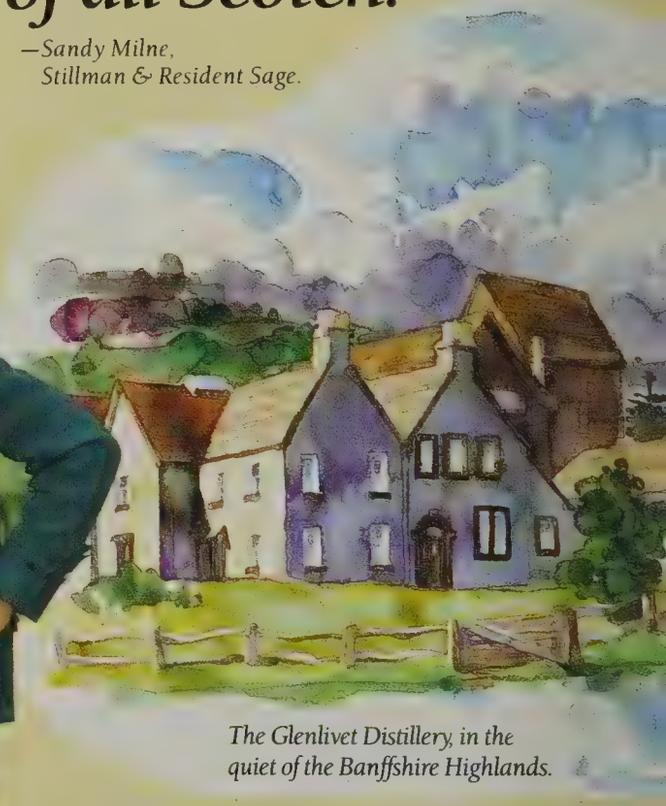
Of particular concern to paleoanthropologists is establishing the age of early Asian artifacts. In China, a number of sites are now reliably dated (by paleomagnetic evidence) to approximately one million years ago, and a variety of dating techniques suggest the earliest fossils and artifacts of *Homo erectus* on Java (so-called Java man) are somewhere between 800,000 and 1.3 million years old. In mainland Southeast Asia, however, artifacts demonstrably older than 100,000 years have long been elusive. Paleomagnetic studies have not yet been carried out to check our estimated biostratigraphic age of 700,000 years for Kao Pah Nam, but both radiometric and paleomagnetic studies were conducted at another site, Ban Don Mun. Artifacts beneath a basalt flow at that site can be assigned an early Pleistocene age of at least 700,000 years. For stratigraphic reasons, artifacts from a nearby site, Mae Tha, can also be accorded that antiquity.

One thing that still eludes us in mainland Southeast Asia are the fossils of the hominids that made the artifacts we have found. As we learn more about their environment, technology, and diet, however, we can see how capably they adapted to a land of bamboo and karst. □

E. S. Ross

"The Glenlivet® is Scotch the way it was originally. Indeed, it is the father of all Scotch."

—Sandy Milne, Stillman & Resident Sage.



The Glenlivet Distillery, in the quiet of the Banffshire Highlands.

"...The Glenlivet is respected as the most elegant of whiskies...its palate clean but sweet; its finish a soothing caress."
—Michael Jackson, The World Guide to Whisky.

"[The Glenlivet] is worth all the wines of France for flavour and more cordial to the system beside."
—Sir Walter Scott, St. Ronan's Well.

In the early 19th century, His Majesty's Government, as governments are wont to do, was levying whopping great taxes on whisky. The Scots, on the other hand, believed it was their inalienable right to make whisky, and taxes be damned.

The result was a land awash in illicit stills, all making what we now know as single malt whiskies. There was even a still bubbling away under the Tron Church in Edinburgh's High Street.

Mercy!

The Government, as governments are *not* so wont to do, eventually came to its senses. In the Act of 1823, the tax was mercifully reduced.

The following year, George Smith, maker of The Glenlivet, went straight. He applied for, and received, the first licence under the Act t legally distill whisky in the Highlands.

So it was that The Glenlivet single malt Scotch whisky becam known as the father of all Scotch.

Foxing the foxes

It having been discovered tha the distillery ducks were being eaten by non-distillery foxes, The Glenlivet opened a miniature "distillery" in 1988 to

How the Scots drink it

"Over here, we usually drink our single malts at room temperature. No ice. Just a small splash of cool spring water to bring out the 'nose,' or aroma. Do that with The Glenlivet and you'll have yourself something that's smooth and rounded, very elegant and subtle. 'A taste of Heaven before the trumpets blow,' as we say."
—Sandy Milne, our Resident Sage.

safely house its ducks. The ducks do not appear particularly grateful.

The world's biggest classical concert?

If you happen to be in Scotland next August, do come to The Glenlivet Fireworks Concert at the Edinburgh Festival. Last time around, over 200,000 people came. They seemed to get a big bang out of it. (Sorry about that.)

"No excuse is needed for giving this whisky pride of place among the malts, for The Glenlivet has been the prince of whiskies for over a hundred years."

—R.J.S. McDowall,
The Whiskies of Scotland,
New Amsterdam Books/
The Meredith Press.

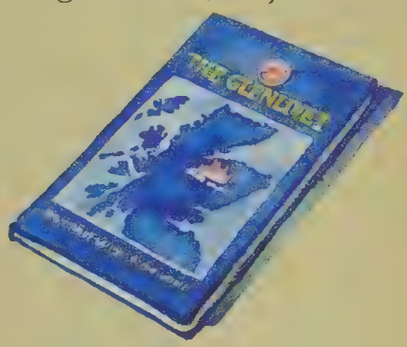
What is a single malt Scotch? And should you give a hoot?

A single malt is Scotch the way it was originally: one single whisky, from one single distillery. Not, like most Scotch today, a blend of many whiskies.

The taste of a single malt can range from light and sweet all the way to pungent and earthy.

The Scotch that most Americans drink is blended whisky, a more recent invention. It is mostly less-flavourful grain whisky with single malts added as a "top dressing" to give the blend character and flavour.

Blended whisky is therefore like a mixture of wines from different vineyards. A single malt whisky like The Glenlivet, on the other hand, should be compared to a château-bottled wine.



Our Little Story

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The Father of All Scotch.

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THE CARIBBEAN

Mysterious flashing lights, orgies deep beneath the seas, and the delicate odor of delicious foods . . . all parts of an exotic region that draws migrating birds and tourists, as lands to the north settle down for a long winter's nap.

David Doubilet

Grouper Sex in Belize

On the sixth day after the full moon, the fish's annual rites of courtship and spawning reached a climax

by Jacque Carter

I had dived on this reef just two days before, but today the number of coral heads and sponges seemed to have suddenly tripled or quadrupled. As I descended, the objects on the reef became clearer—they were Nassau groupers, thousands of groupers, weighing from five to twenty pounds or more. The school seemed endless. Probably five to ten thousand groupers were swarming over the reef like bees on a hive.

Normally brown banded with a dark stripe through the eye, the groupers had taken on all kinds of colorations. Some were stark white; others, all black or all brown. And some were white on one side and black checked on the other.

Shortly before the first full moon of every year, Nassau groupers begin to arrive off reefs throughout the West Indies. The females' eggs ripen over the next several days, and usually on the third evening after the full moon, the eggs are released and fertilized by the males. The spawning might continue for several more days, but by the new moon, nearly all the fish will have disappeared. I know of six such Nassau grouper spawning sites off Belize. All are in 80 to 120 feet of water, just at the edge of the drop-off where the reef meets the deep blue ocean. Since 1984, with the support of Wildlife Conservation International, a division of the New York Zoological Society, and the government of Belize,

I have been making my own annual migration to Cay Glory, trying to find out what attracts these fish in such large numbers and at such a specific time of the year.

Belizean fishermen have long exploited this gathering. In the shoals of Cay Glory they construct temporary shelters on stilts and wire-mesh holding pens in which they keep the fish alive until they can move them to market. Just seaward of the "stilt city," the reef crest breaks the surface at low tides. Beyond, at a depth of thirty to forty feet, the ridges formed by star corals, other hard and soft corals, and algae and sponges of assorted shapes and colors slope downward toward the drop-off. There are changing currents here and schools of small reef fishes. From time to time a spotted eagle ray comes winging along one of the valleys, soars over the top of a coral ridge, and disappears down the reef, or a sea turtle rows by with its powerful front flippers. Inside the many holes on the reef, large spiny lobsters poke their armored antennae forward while keeping their succulent tails tucked securely behind them.

The lobsters and the many species of small tropical fishes are all potential food for the groupers, but most are not interested in food; they have other things on their minds. Although fishermen derive a major portion of their annual income from fishing this gathering, only fish on the edge of the group seem to be attracted by a baited hook. And the fishermen will tell you that when the fish stop feeding altogether, the spawning begins.

The reef at first seems an unlikely, if not dangerous, place to breed. The limpid waters in which coral reefs develop are essentially devoid of the organic matter upon which life thrives in temperate seas. The level of nutrients in the water could not possibly support the reef's diverse and productive plant and animal life. Instead, reef life depends upon a rapid and efficient system of nutrient cycling. Minute plants called zooxanthellae, which live within the tissues of coral animals, pass biological products to and from their hosts with little loss to the surrounding environment. Any food that becomes available is rapidly consumed and recycled.

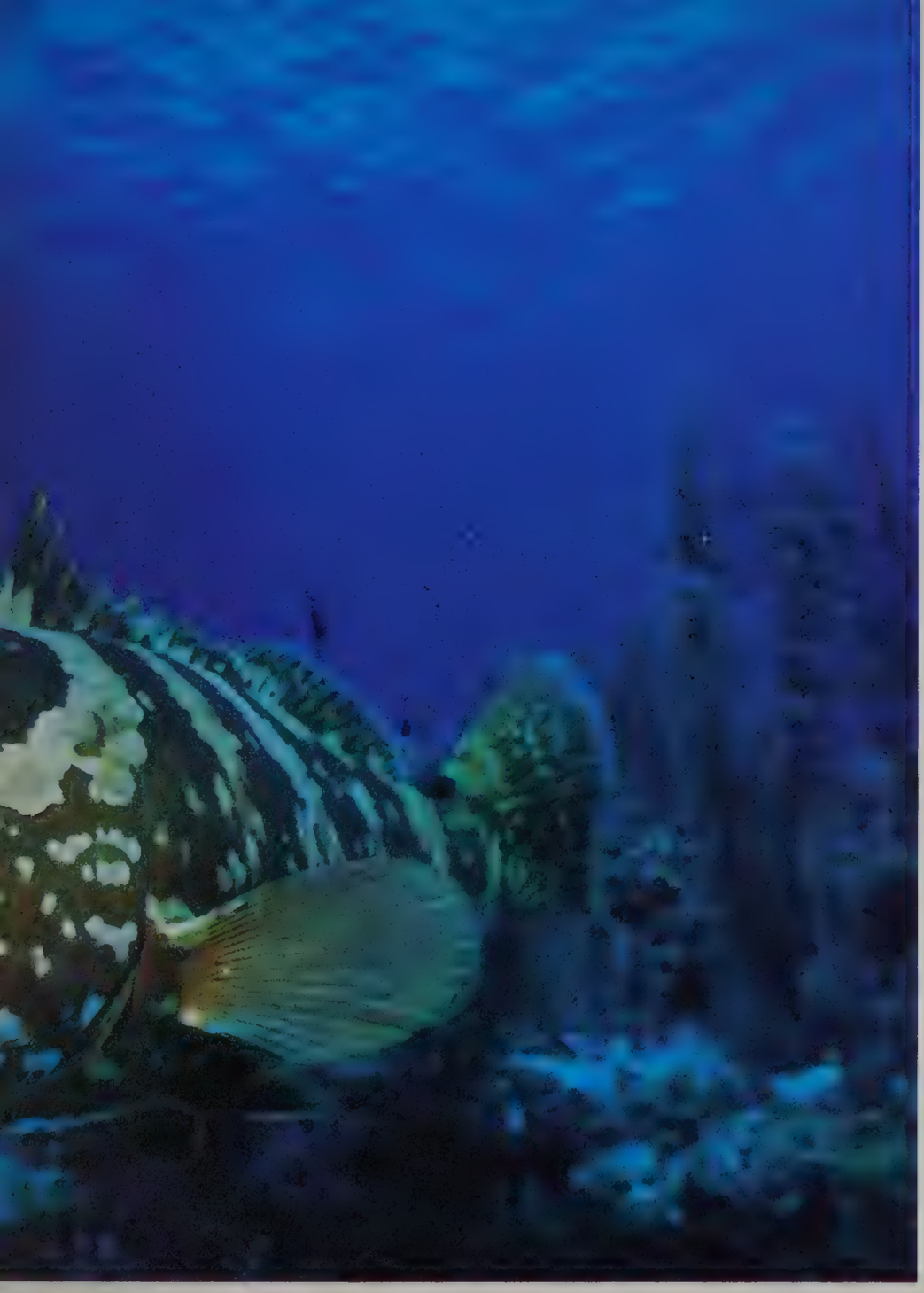
Doug Perrine

Scavengers and predators constantly roam the reef, consuming every available bit of organic matter (a dead fish is a rare sight). This is good for sanitation, but it creates a problem for the fish eggs. Each developing embryo is provided with a yolk, a small sac of concentrated and highly nutritious food, but this yolk also attracts any marine creature that can gobble it down.

Fish that lay their eggs on the reef, such as damselfish, are forced to guard them continuously until they hatch. In spite of mounting a tireless defense, the parent (frequently the male) may be overwhelmed by marauding wrasses, which specialize in seeking out and consuming the eggs of other fishes. Jawfish go so far as to incubate their eggs in their mouths for protection. Other fish just release their eggs into the water, often at dusk, thus giving them a twelve-hour head start against the egg eaters.

As darkness falls on the reef, pairs or small groups of fish swoop up toward the surface to release eggs and milt. The larvae that survive to hatching must then run the gantlet of planktivorous fishes and hungry coral polyps; the latter reach into the water with tiny tentacles, each tipped with a stinging "harpoon" capable of killing or immobilizing a developing fish. Also dangerous are the filter feeders, such as sponges and tunicates, which constantly pull the reef waters through biological sieves capable of filtering out edible organisms as small as bacteria. To beat the odds, most reef fishes produce thousands and thousands of eggs.

Some fishes have "found" (in an evolutionary sense) that the best chance for survival of their offspring is to release



C. C. Lockwood; Bruce Coleman, Inc.

Left: The Nassau grouper spends most of its adult life in one small area near the reef bottom, waiting for its primary prey, smaller fish. Below: Groupers living in deep water often take on a red hue not seen in their shallow-water counterparts.

their eggs away from the reef. Although leaving developing larvae drifting helplessly offshore might seem an improbable advantage, the chances of being lost in the vastness of the ocean, never to return, may be more than offset by the chance that a few organisms will survive until they are large enough to have a fighting chance back on the reef. Many species have found ways to maximize this advantage. Spawning frequently occurs on the full and new moons, when tides are highest and most likely to sweep eggs away from the reef. The time of year may also be "chosen" to take advantage of seasonal changes in currents that might affect dispersal of the larvae.

The most critical factor may be the spawning place itself. A number of different species of fish often hold their reproductive rites at the same location. Commonly, the spot that attracts all the activity is an underwater promontory. The turbulence caused by currents flowing past such projections often produces gyres that carry the eggs offshore for the developmental period, then return the larvae to the reef to begin their adult lives. Some marine organisms can apparently remain in the larval stage for an indefinite period, until return to shallow water triggers the metamorphosis to the adult form and settling onto the reef. Because gyres are most likely to form on the down-current sides of islands and atolls, spawning grounds are most often located here.

In contrast to the Indo-Pacific, tides in the Caribbean fluctuate very little (about seven inches in Belize) and probably play a minor role in water movements. Strong currents do occur, however, and I believe the turbulence created where reef promontories extend into the current moves eggs away from the reef and potential predators. Local populations of groupers may depend on the return of the offspring to the reefs surrounding the spawning ground after the developmental period is completed. Nassau groupers, however, thrive throughout the West Indies, and larvae don't have to return to their exact point of release in order to survive. They merely have to find suitable habitat.

Grouper larvae, which are immediately

Left: As spawning approaches, the groupers begin to change colors and interact. Below: Even outside of the spawning season, groupers have a small repertoire of colors; this one is in a brown phase.

Both photographs by Doug Perrine

recognizable by their extremely elongated dorsal spines, generally develop in about twenty-four days. During this period the spine, which aids in flotation and may provide some defense against predation, is resorbed by the developing fish, so that day by day the larva actually grows shorter. Eventually it leaves the surface and begins descending, delaying its final metamorphosis until it finds an appropriate spot to settle. If the larva fails to encounter a gyre and spends three weeks moving along in a two-knot current, which is common along the barrier reef, it could travel more than 1,000 miles from its point of origin. While such a long trip in one direction is extremely unlikely, the larva may easily be transported far from the breeding area where it was released. How then would a fish that settled far outside of the spawning area of its parents know where to breed?

If maturing fish learn the location of spawning areas by following experienced fish, the loss of older, larger fish by fishing could destroy the population by eliminating knowledge of suitable spots for reproduction. But I believe the fish are guided by an instinct that compels them to move to the edge of the drop-off and follow it until they encounter a suitable spawning location, that is, a promontory. I have no doubt that once it has participated in a spawning, a grouper can remember the exact location and return there again. Groupers are intelligent, visually oriented fish with impressive navigational abilities. I once captured one, held it in captivity for six weeks, tagged it with an ultrasonic transmitter, and then released it two miles away from its point of capture. The grouper made a beeline for the exact rock from which it had been removed one and a half months before.

I have found that other species also make use of promontories, or drops. The site used by the Nassau groupers in December and January is used by black groupers in January and February, and by other species in later months. One morning in 1988, after a spawning school had vanished from the Cay Glory site overnight, photographer Doug Perrine and I drifted down the reef toward the second and third drops, with an underwater video camera dangling below the boat. When a huge school of fish appeared on the screen, Perrine jumped overboard and swam downward. At about 100 feet he found a densely packed ball of thousands of dog snappers. As he approached, the snappers began to stream over the drop-off, descending to a depth of more than 200 feet before suddenly turning and rushing back toward the surface. At a depth of perhaps twenty to thirty feet below the surface, the fish again formed a huge ball, then streamed downward before disappearing over the "wall."

Among these snappers, Perrine found a small group of Nassau groupers flashing colors as if joining the snappers in their spawning rites. We noticed that when the Nassau groupers began to get excited, so did the few groupers of other species that were present on the banks. The fish may have been indicating their readiness to mate not only by flashing colors but also by releasing chemical signals known as pheromones. If the chemical structure of the pheromones used by different species is sufficiently similar, a chemical released by one species could trigger a response in another.

Lunar cycles also affect spawning in many of these species. Spawning on full-moon tides in the tropical regions of the Pacific allows eggs to be swept safely away from the reef. In the Caribbean, where fluctuations are minimal, the advantage is less clear. The moon may merely provide a convenient cue for synchronizing the behavior of the thousands of fishes involved. Interestingly, spawning on the third day after the first full moon of the year also seems to be observed by fishes in some parts of the Bahamas, but elsewhere in the Bahamas, spawning aggregations have been recorded on other lunar phases. In Bermuda, examinations of fish ovaries indicate that spawning there may occur as late as May to July.

In January 1988 the sky was heavily overcast, and the moon was obscured for about two weeks. On the third day after the full moon, groupers moved down to the drop-off, but failed to spawn. Over the next two days the fish remained near the drop-off, and courtship behavior continued to increase, but I did not see any spawning. Finally, at sunset on the sixth day after the full moon, courtship appeared to be reaching a climax as the fish began to rise from the bottom and to chase

one another in groups. Darkness cloaked the finale of the spectacle, and by morning the fish had disappeared. Although fishermen report that penned fish usually spawn at the same time as the fish on the reef, the majority were still holding their eggs two days later when they were cleaned for market. Only late in the morning of the seventh day did we encounter the small group of groupers spawning among the snappers farther down the reef. The fish may have waited for the visual cue provided by the full moon until they finally began to spawn sporadically without the group coordination synchronized by their lunar "clock."

The need to coordinate spawning is critical for groupers. They are large, solitary fish that do not usually stray far from their territories. Four groupers that I tagged with ultrasonic transmitters all stayed

Lighthouse Reef, left, is one of three grouper spawning grounds off Belize. Below: When the fish are running, fishermen live on platforms in the lagoon behind the reef. Below, left: The fish are held in "live pens" until ready for market.

Photographs by Doug Perrine

within a range of 2 to 300 yards. With this type of life style, they encounter few prospective mates. Some schooling fish, such as surgeonfish, and fish, such as wrasses, that are abundant on the reef may travel to the edge of the reef each day to spawn. But this is not feasible for groupers. The distances are too great and food is just not available.

Annual mass groupings may also allow the fish to assess the ratio of males to females in the total population. This is important because Nassau groupers, like many other members of the sea bass family (Serranidae), are protogynous hermaphrodites: they mature first as females and later may reverse sex and breed as males. Sex reversal does not occur automatically when a certain size or age is reached. Some fish change not long after laying eggs for the first time, some change late in life, and some apparently spend their entire lives as females.

During the several days of courtship that precede spawning, I have often seen small groups of a half-dozen to a dozen fish forming and flashing various color patterns. One function of these color phases—exhibited only during breeding—may be to advertise the sex of the individual. Depending upon the sex ratio of the breeding population, one gender may have a greater reproductive potential than the other. Assessing the number of males and females in the population would be vital in determining whether or not to reverse sex before the next spawning migration. But once having reversed, a male can never change back to female.

The range of color patterns seen during these aggregations far surpasses that needed to identify a fish as either male or female. The most common abnormal pattern, dark on top, light on bottom, is seen in late afternoon, as the time for spawning approaches. In advanced stages, fish have a white streak across the eye where normally a dark stripe passes. These bicolored fish display the most aggressive behavior, chasing and nudging other fish in light to normal color phases. Because of this "male" behavior, some investigators have suggested that the bicolor fish are males. To confirm this is difficult, because the fish rapidly revert to their normal coloration when disturbed, making it impossible to capture one in this phase. In 1987 I was able to spear five that had been observed in the bicolor phase. All were males. In 1988, though, one of the penned fish that had been observed flashing the bicolor pattern and chasing other fish turned out to have ripe ovaries. A great deal more study will be necessary to decipher the significance of these elaborate costumes.

The basic mechanics of spawning remained largely unknown until this year. Many fishermen believed that the groupers moved off the reef into deep water and formed a huge ball or cone-shaped school, much like the snappers that we witnessed. This posed a number of questions: Were all the eggs and sperm released in a large cloud with fertilization occurring by chance? Did pair or group spawning occur within the school? Weather and circumstance combined for many years to hide this phenomenon from my eyes, and I was unable to find any film, photos, or documented observations of the actual spawning event. Finally, in January 1989, the mystery was partly solved when my colleague Patrick L. Colin, of the Caribbean Marine Research Center, ob-

Doug Perrine

The first photograph of grouper spawning, below, taken this year, revealed milt flowing from the males. Opposite: Dog snappers spawn en masse off the same underwater promontories used by groupers.

Lori J. Bell

served and videotaped the spawning of Nassau groupers off Long Island in the Bahamas. Colin reported that prior to spawning, the aggregation of about 500 fish moved from water 60 to 80 feet deep out to a depth of about 130 feet. Then, right at sunset, groups of 20 to 40 fish rushed toward the surface, releasing their reproductive products at a depth of approximately 80 feet. The videotape shows that nearly all the fish in the aggregation assumed the bicolor phase prior to spawning, negating the idea that all bicolor fish are males.

The Long Island spawning aggregation is one of many that have been subjected to heavy fishing pressure. And, like many, the aggregation was much smaller this year than in previous years. Fish with ripe eggs have been found only among breeding aggregations. This means that if overfishing or disturbance of the habitat destroys a breeding aggregation, that population might fail to reproduce.

Some breeding aggregations have already been lost. One in Saint Croix vanished only ten years after it was discovered, during which time it was fished heavily, by sharks as well as by fishermen, who reportedly cleaned their fish over the bank, attracting the sharks. At Cay Glory, by contrast, the penned fish are kept alive until the spawning run ends, then cleaned in shallow water in the back reef area. Any sharks that approach are dispatched with a machete and added to the catch. The use of fish traps in the Virgin Islands and the Bahamas may help to explain the prevalence of sharks at these aggregations. The sharks are attracted by the smell of dead bait used in the traps, by the sound of live bait placed in them, and by the vibrations of the trapped groupers. The traps may also contribute to the overexploitation of the aggregations by allowing fishermen to catch groupers that are not feeding.

A spawning ground can also be destroyed by excessive hook-and-line fishing. For two years after its discovery in the mid-1970s, an aggregation at Rocky Point, Ambergris Cay, just north of the Belizean fishing village of San Pedro, was fished intensively by the local fishermen. In the third year the fish failed to return. I have yet to locate any aggregation within a radius of thirty miles of this formerly productive bank. In an effort to locate the nearest active spawning bank, I captured two local groupers and implanted ultrasonic transmitting tags into their bodies just before the spawning run of 1986. I eventually lost track of both, presumably en route to the spawning location. To my amazement, more than a year later I received a call informing me that one of my transmitters had been recovered from a grouper taken from a spawning aggregation off the central part of the Yucatan Peninsula of Mexico, more than 150 miles north of where I had lost track of the fish. I have wondered if, since the overexploitation of the Rocky Point bank, many of the groupers of the northern reef province of Belize now make this incredible migration to satisfy their reproductive yearnings.

The Cay Glory fishery has experienced a tremendous decline since it began in the 1920s. The catch has gone from more than 100,000 pounds per year to less than 30,000 last year. The fish are also, on the average, smaller, and the sex ratio has become skewed. At the spawning ground at Lighthouse Reef, Belize, which is relatively undisturbed, the catch is about 37 percent male. At Cay Glory, males make up only 25 percent of the catch.

The Rocky Point incident raises the hope that even when overfishing wipes out spawning aggregations, some of the surviving fish may be able to reproduce by participating in more distant groupings. Nonetheless, I think the remaining spawning grounds ought to be identified and protected. With John Olney, of the Virginia Institute of Marine Science, I will attempt to follow the movement and development of larvae by releasing a fluorescent dye into the water as close as possible to the moment of spawning. The trail of dyed water will, we believe, show the movements of the larval fish.

We may never know what goes through the minds of those fish as they gaze up at that New Year's full moon and change their old brown colors for black-and-white formal wear, but we plan to find out where they've been and where they're going, and we hope that our incessant probing will help to provide them with a guarantee that they will be able to celebrate their ancient ritual for years to come. □

Let's dig a little deeper into the notion that much of our garbage is made up of plastics.

America's growing waste problem is monumental. We generate 160 million tons of garbage a year.

Our nation's landfills are being filled up. In five years 2,000 of our remaining 6,000 landfills will be closed.

A lot of well-intentioned solutions are being offered. One is that foam plastics, plastic bottles and plastic packaging should be banned.

The fact is that plastics make up less than 8%, by weight, of our nation's waste. Paper and paperboard make up about 36%, glass and metal about 9% each, all by weight. Plastics are naturally lighter, but still, when compressed, account for only about 20% by volume.

If plastics were banned, the need for packaging wouldn't go away. The idea is to substitute other materials which are assumed to be biodegradable, so a landfill would take longer to become full. Studies show, however, that paper and other materials decompose so slowly in today's landfills that the lives of the landfills are not extended.

Recycling must play a part.

In addition to environmentally secure landfills, and more state-of-the-art waste-to-energy incinerators, we believe that a significant answer to America's waste problem lies in recycling. Everything recyclable should be recycled. Yard waste. Paper. Metal cans. Glass bottles. And plastics.

Although plastics recycling is in its infancy, plastics are potentially more recyclable than alternative packaging materials.

In South Carolina, one company recycles 100 million pounds of 2-liter plastic soft drink bottles a year into everything from fiberfill for ski parkas to scouring pads to automobile distributor caps.

In Chicago, another company processes 2 million plastic milk jugs a year into thousands of boards of "plastic lumber" for boat docks, decking, park benches and fences.

In Tennessee, another company processes plastic containers into bathtubs, shower stalls and sinks.

What Amoco Chemical is doing.

Amoco Chemical is playing an active and meaningful role in recycling.

We're sponsoring a demonstration recycling program in New York State showing that used polystyrene foam food service containers from schools and restaurants can be recycled into products like insulation board for commercial construction, cafeteria trays and home and office products.

We're participating in a consortium with other major plastics manufacturers which will support construction of regional recycling plants as part of a nationwide attempt to increase the recycling of polystyrene.

In Portland, Oregon, we renovated a 10-acre environmental learning center with a new wetlands walkway, signs, kiosks and benches made from recycled plastics partially collected from local recycling programs.

We're encouraging the start-up of new plastic recycling efforts, we're helping to find new ways to collect and sort recyclables, and supporting efforts to create markets for products made from recycled plastics.

At Amoco Chemical, we believe we're only beginning to see the benefits of recycling. In the not-too-distant future, it can turn our solid waste from a national problem into a national resource.

For a free copy of "Recycling. Do It Today For Tomorrow," write Amoco Chemical, 200 East Randolph Drive, Chicago, IL 60601.

Recycling. Do It Today For Tomorrow.

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A brittle star clings to a sponge
Doug Perrine

Starlight on the Reef

Some brittle stars of Caribbean and other tropical reefs glow with displeasure when touched

by Matthew S. Grober

Susan C. Speck

Brittle star arms emerge from tube sponges, a favorite daytime hide-out.

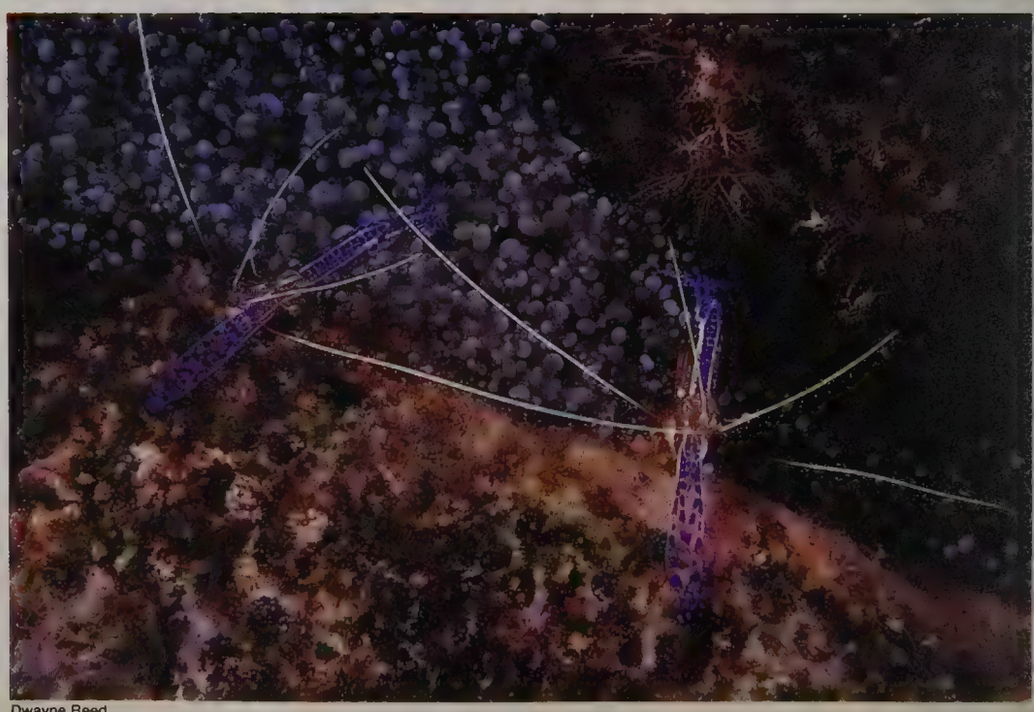
Although suspended a few feet below the surface of the Caribbean Sea, I could still watch the sun set, its last rays of light refracted downward by the water. The colorful fish that cruised the reef flats, off the Smithsonian Institution's field station in Panama's San Blas Islands, were searching for a place to rest for the night. By gradually settling to the bottom, they avoid exposure at the most dangerous time of the day, when the low angle of the light sharpens silhouettes and makes them easy prey for the occasional large fish hunting from below. In the twilight I could see many of the sedentary reef dwellers emerging from their daytime shelters to feed in the relative safety of the darkening reef bottom. In addition to the blooming coral polyps, basket stars, and other invertebrates, luminescent brittle stars, the focus of my research, were making their appearance.

What light still filtered down through the water enabled me to distinguish hundreds of spindly brittle star arms extending like spaghetti from the empty heads of coral skeletons and other crevices in the reef. Within twenty minutes after sunset, parts of the reef were carpeted with the animals, their snakelike arms stretching into the gentle bottom current. On each arm, hundreds of tiny tube feet, sticky with mucus, trap food particles suspended in the water, passing them along the arms to the brittle star's mouth on the underside of its body, a thin disk slightly smaller in diameter than a dime.

Most of the fish that would readily attack an exposed brittle star retire after dark, but the nighttime reef is still a dangerous place for this slow-moving animal. In addition to nocturnal fish, a variety of nocturnal crabs, lobsters, and shrimp pose an even more serious threat to brittle stars. But these small echinoderms have evolved

Stephen Frink; The Waterhouse

Not all brittle stars sweep the currents for food. Moving slowly past an outcrop of anemones, a brittle star, above, collects food from the surface of the reef. Cleaner shrimp, right, are among the few crustaceans that pose little threat to brittle stars.



Dwayne Reed

Although it has lost part of one arm to a predator, the brittle star below can quickly repair the damage by regenerating the tip of its limb.
Michele Hall

a number of defenses against attacks from the many crustaceans that prowl among the corals.

Since it need only keep its five arms exposed for feeding, a brittle star's central disk is usually hidden. When threatened, the brittle star retracts its arms and crawls back into its shelter. This retreat can be relatively swift. Should a crab attempt to pull the brittle star out by an exposed arm, the limb will readily break off before the whole animal can be budged. The ease with which this happens gives the brittle star its popular name. Although sacrificing a limb may seem like a drastic measure, most brittle stars can regenerate a missing arm in a matter of weeks. If many arms are lost, however, the brittle star may require more time to regenerate. Nevertheless, the loss is a small price to pay in exchange for its life. Even a damaged central disk can be repaired by some species.

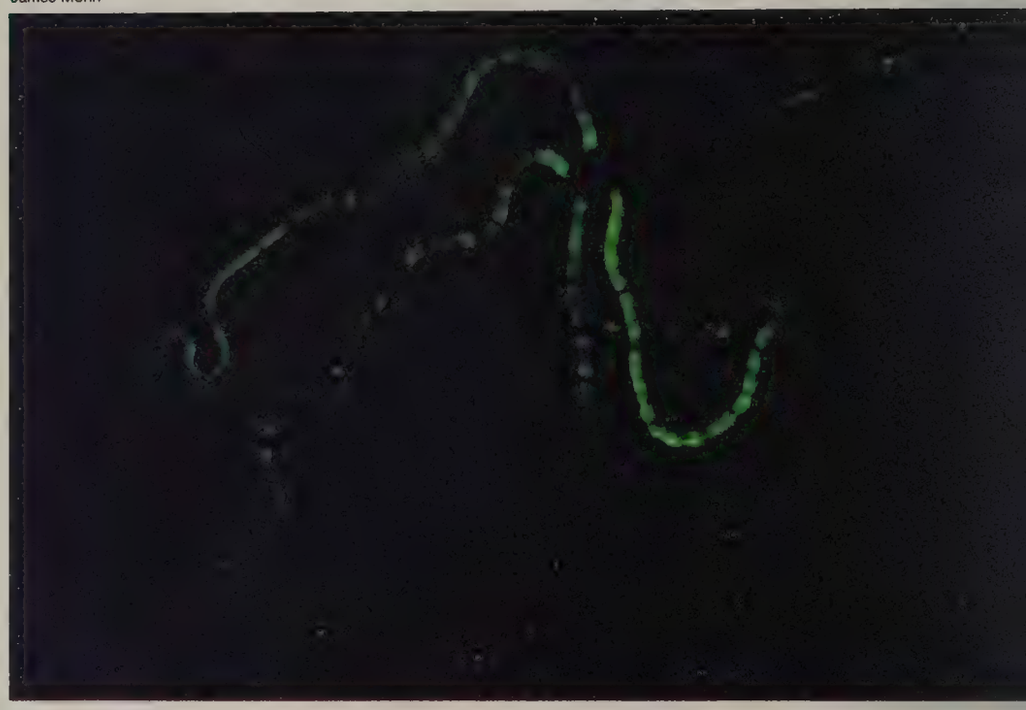
About 13 percent of brittle star species, including those in the genus *Ophiopsila,* are capable of luminescence. I studied *Ophiopsila riisei,* a common inhabitant of shallow reefs in the Caribbean, and on several occasions I watched as a predator ripped an arm off an unfortunate brittle star. The detached arm, still writhing in the grip of the attacker, produced continuous waves of bright green light that traveled up and down its length. As the distracted crab or lobster grappled with the arm, the rest of the brittle star remained dark, and the animal crawled back into its hiding place.

In some cases, luminescence prevents such attacks altogether. In the blackness of the nighttime reef, as many as fifty faint flashes a minute, resembling twinkling stars, can be seen emanating from clumps of brittle stars. Because *Ophiopsila* glow in response to the slightest touch, mild responses are elicited when plankton and other matter being swept along in the current collide with the brittle star's arms. But I observed stronger green flashes, bright enough to be seen from twenty-five feet away, punctuating the dark about ten times an hour. By swimming to the site and shining a dim red light on the reef, I could see what was causing these bright flashes without disturbing any crustaceans that might be present (crustaceans' eyes are not sensitive to red light). About three times out of ten, I arrived too late to catch the action, but the other times I saw a predator retreating from a brittle star, whose arms often remained whole and undamaged.

A survey of the *Ophiopsila* on the reef revealed that only 7 percent of their arms were damaged or missing. This amount may seem high, but not when compared with the 35 to 75 percent of arms missing from nonluminescent species living on the same reef. Because the flash defense enables *Ophiopsila* to escape many attacks with a minimal disruption, the luminescence has the added benefit of allowing the animal to keep its arms deployed longer for feeding. The average individual lost only seven minutes of feeding time per night while retreating into its shelter to evade predators.

When the brittle star Ophiopsila californica *is disturbed, nerve cells in its arms trigger a chemical reaction that produces a bright, yellow-green light. If a predator grabs this echinoderm, waves of luminescence travel along the animal's writhing arms, below. Its central disk hidden in a reef crevice,* Ophiopsila riisei, *bottom, extends its sinuous arms into the current to feed.*

James Morin



These field observations, as well as experiments I later conducted in aquarium tanks, show how luminescence benefits *Ophiopsila,* but the question remains: How do the flashes deter predators from eating the brittle stars?

One possibility is that the bright flash startles the predator long enough for the brittle star to withdraw into its crevice. Similar startle mechanisms are believed to account for the eyespots that many caterpillars and butterflies flash when disturbed. This sudden signal may frighten off bird predators.

Likewise, the brittle star's flashes may serve to temporarily blind a predator. Just as a flashbulb leaves a bright afterimage on our eye, the flash of a luminescent brittle star may render a predator unable to see clearly, thus reducing its chances of catching the prey.

Nancy Sefton

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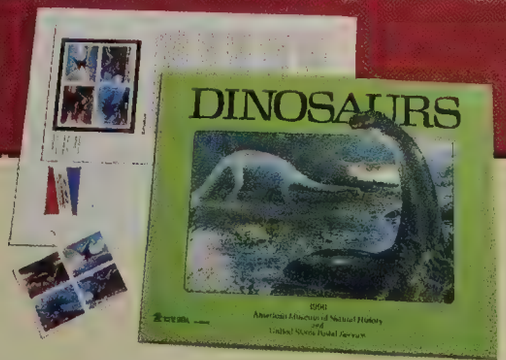

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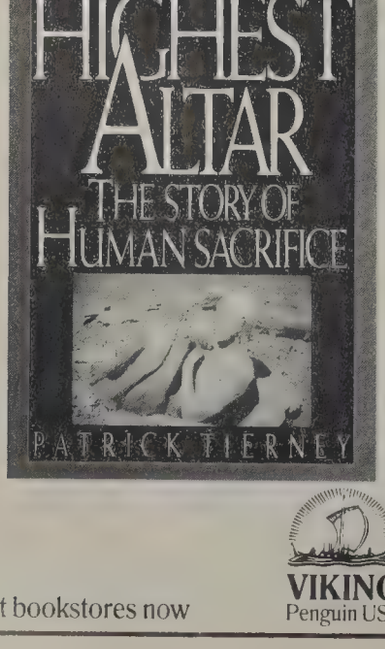

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The large-eyed red shrimp is adapted for nighttime stalking on the reef. Although it preys on brittle stars, it shies away from luminescent species.

Chris Huss

My experiments with brittle stars and crabs in aquariums suggested another way the luminescence might deter predators. When *Ophiopsila* were rendered nonluminescent with a mild anesthetic, the crabs handled them for extensive periods, ripping off arms and chewing on the parts, rather than rapidly moving away as they would in response to a flash. Nevertheless, I was surprised to find that even *Ophiopsila* deprived of their luminescent defense fared better than nonluminescent species. Although *Ophiopsila* were often mangled by their attackers, they usually managed to survive, whereas *Ophioderma cineruem,* which are incapable of luminescence, were readily eaten and rarely survived an encounter. Evidently, some characteristic of the arms of *Ophiopsila,* other than their luminescence, was dis-

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ROYAL CARIBBEAN

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Hermit crabs are among the many small reef animals often found in the vicinity of the luminescent brittle stars—perhaps seeking the protection offered by their flash defense.
Doug Perrine

couraging the crabs from dining on them. Perhaps steroid-based chemicals, similar to those found in other echinoderms, such as sea cucumbers, render *Ophiopsila* distasteful to the crabs.

By offering a variety of brittle star species to the crabs, I confirmed that *Ophiopsila* was not a favorite. Its unpalatability made me think that the luminescence might function as an aposematic, or warning, signal to a predator that this brittle star is not good eating. Once a crab has learned that luminescent brittle stars are distasteful, a flash may be enough to deter it in the future. A well-known example of such warning signals is the bright coloring of the monarch butterfly. A study by Lincoln Brower, of the University of Florida, showed that blue jays that had eaten a poisonous monarch learned from the unpleasant experience and avoided monarchs in the future. Indeed, birds are known to reject not only the monarch but also the nontoxic viceroy butterfly because its colors mimic the monarch's.

The brittle star is probably not unique in its defensive use of luminescence; corals, tube worms, and other invertebrates that are unable to move rapidly away from predators also glow when disturbed. Some dinoflagellates (tiny planktonic organisms) may produce aposematic flashes in a manner similar to *Ophiopsila*. These dinoflagellates are known to be toxic, and their signal may discourage the tiny crustaceans called copepods from eating them. Perhaps the ability to associate the luminescent signals with toxicity can be inherited by extremely simple organisms. Although some coastal marine animals have been found to use light flashes to attract mates and prey, James Morin, of the University of California at Los Angeles, believes that the majority of these signals are for defensive purposes.

Many other animals may take advantage of the brittle star's defense mechanism. I have often seen small shrimps or hermit crabs hiding in and around the arms of *Ophiopsila*, and moving about so gently that they do not induce bright flashing. These organisms may be taking shelter "under the eaves" of the brittle star's arms, since predators (of both *Ophiopsila* and their guests) are kept away by the luminescent flashes. Or they may be using the arms of the brittle star as an "electric fence" that will produce a bright flash of light when a predator is near. By providing advance notice of the impending danger, this warning flash allows the shrimps and crabs to escape to safer quarters. What works for *Ophiopsila* undoubtedly works for others. ☐

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THE CARIBBEAN

The Coconut Trail

How did the giant seed come to preoccupy the cooks of Caribbean Colombia?

by Raymond Sokolov

The history of food is a gentle and harmless pursuit in the eyes of the world, but it also gives its adepts some heavy facts to wield. For example, the next time some French high-school-dropout waiter says something scornful about American food, you can remind him that this raw and callow hemisphere had *haricots verts* before Joan of Arc heard voices or that modern cultivated strawberries are a gift from Chile and Virginia.

As we learn in *Jane Grigson's Fruit Book* (Atheneum, 1982), from Charlemagne to Chardin, the French had only wild strawberries, those little *fraises des bois* that are "a little seedy on the tongue," as Ms. Grigson puts it.

Meanwhile, early Virginian settlers battened on their own wild strawberry, *Fragaria virginiana,* grew it, and let it be taken to England and Europe where it held on to its New World virtue and would not cross with Europe's wild strawberries. It wasn't until almost the 1800s that a French botanist, Antoine Nicholas Duchesne, thought to plant the scrappy little *F. virginiana* near *F. chiloensis* (brought back from South America's Pacific coast to Brest). The rest is fruit history and a tribute to American vigor, so often sneered at in France, and to American finesse, so seldom admitted to exist. Really, we should confiscate their French fries and send them home to Peru.

Of course it is true that the strawberries we now produce by the carload owe their existence to French and British cleverness. But we still have a right to feel proprietary over strawberries and to feel sensitive if ribbed about them.

This never happens, as far as I know, but the mental exercise of imagining how it might feel may throw a sympathetic light on the peculiar business of black Americans and watermelons. Much ostensibly genial racist humor revolves around blacks and their allegedly ravenous attachment to watermelons. I'm not saying that blacks don't like watermelons. Why shouldn't they? Indeed, food history suggests they have a better reason than the rest of us for being attached to watermelons. Watermelons are roots food, so to speak, for blacks all over this hemisphere, because watermelons are indigenous to West Africa. So when blacks arrived in slave ships in Brazil, Jamaica, and Charleston, they brought watermelons with them. And we are all the better for it.

I thought about this last summer on the beach at Cartagena, Colombia. Black women walked up and down the sand with flat baskets of delicious cut fruit on their heads—mangos, papayas, and, yes, watermelons. These are the *palenqueras,* direct descendants of slaves settled here when Cartagena was the main port of the Spanish Main—Cartagena de Indias, a massively fortified warehouse for the commerce of the Americas.

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The "pantropic" coconut palm

Carl Purcell

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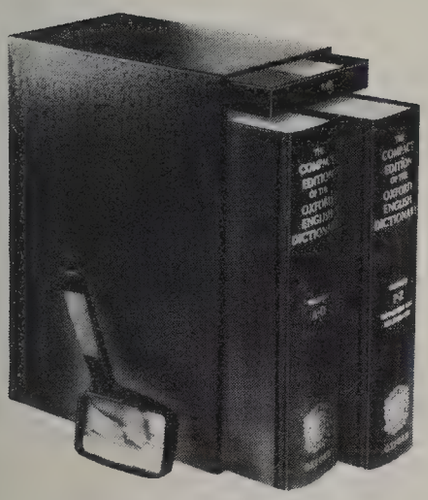

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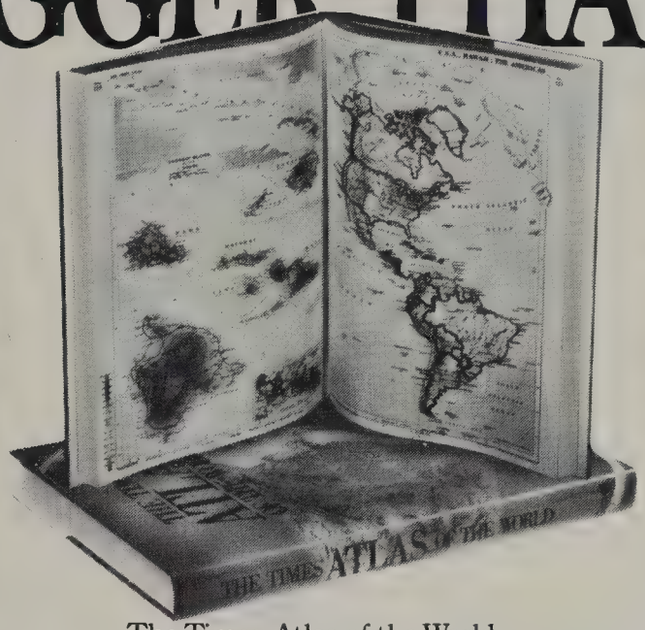

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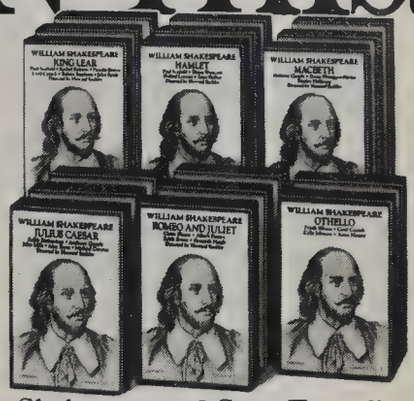

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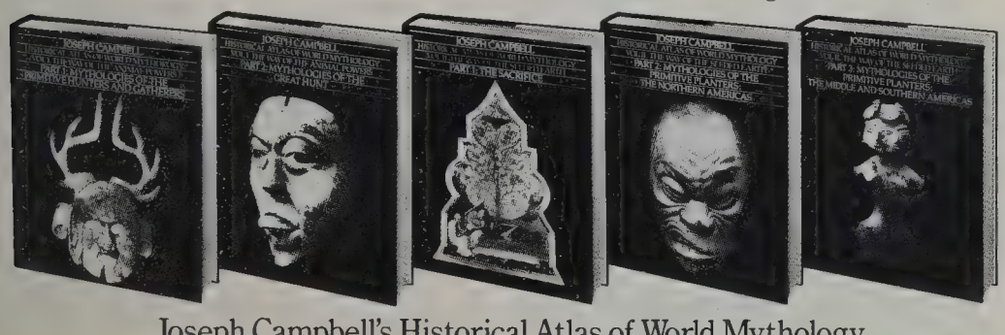

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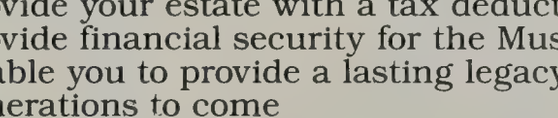

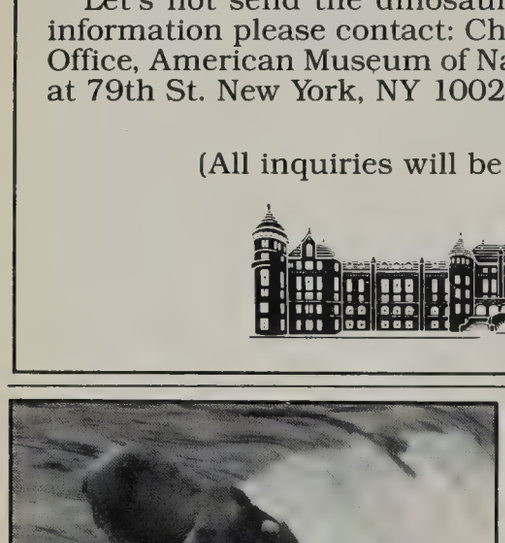

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America. The Spanish called it Tierra Firme in the sixteenth century, to distinguish it from the islands of the West Indies and from Nueva España (the New Spain of Mexico and Central America). Cartagena was settled in 1533 and named after the port in southeast Spain.

In its heyday, Cartagena de Indias (hereinafter simply Cartagena) was a swashbuckling place (captured briefly by Sir Francis Drake). It was the pearl of the vast new Spanish colonial state that came to be called New Granada and that then devolved, during the process of liberation in the early nineteenth century, into the modern countries of Venezuela, Ecuador, Colombia, and Panama. Because of this outcome, the country we call Colombia has two coasts, a Caribbean and a Pacific, seemingly bisected by the Panamanian isthmus where it abuts South America. This is not the only geographic obstacle to the physical unification of modern Colombia. The Andes, as well as various tropical forest regions and a still uninviting road system, have isolated the country into distinct regions.

Cartagena and the other coastal cities of the Caribbean coast have, for example, retained much of the architecture and spirit of their colonial origins through almost five centuries. Cartagena today is an overwhelmingly black city with its own cuisine based on African and local ingredients, Spanish cooking methods, and Spanish ingredients. It goes without saying that seafood is the dominant source of animal protein. But the more important basic element—I am tempted to call it a staple—of the cuisine of Cartagena is the coconut.

Everywhere you go there are producing trees. On the beach, people drink the sweet clear liquid right through a punctured coconut eye. There are dozens and dozens of coconut recipes in Teresita Roman de Zurek's classic *Cartagena de Indias en la Olla* (Gamma, 1987; this is the revised edition, far superior to earlier Spanish editions and the clumsy English translation). There are desserts of every description—puddings, cakes, candies. There is soup. There is chicken with coconut. There is even a dish in which snails are stewed in coconut milk. But the standard, the most characteristic dish of Cartagena is rice cooked in coconut milk, *arroz con coco.*

The basic recipe is a brilliantly simple idea—once you have laboriously grated and squeezed out the six cups of coconut milk from the coconut meat. Then, you are in effect simply substituting coconut milk for the water you might normally use to cook rice. The result is, of course, different. The coconut milk turns caramel

brown and is absorbed by the rice, which takes on a delicate coconut fragrance and a richness of texture. The cholesterol-raising aspect of *arroz con coco* does not recommend it to first-world peoples with life spans long enough to make them concerned about coronary disease. No doubt, this caveat should apply to modern Cartagenans as well, but it does not seem to prevent them from indulging in *arroz con coco* as a side dish with meat, poultry, grilled fish, or fish stewed with plantain, cassava, yam, and potato in the bouillabaisse of the Caribbean, the *sancocho. Arroz con coco* even appears as a dessert with chocolate.

Arroz con coco is not only ubiquitous; it is a minicuisine, including many variations. Even a brief visit to Cartagena will turn up more than one. In the simplest sort of palm-thatched restaurant, called La Caimana, in the black fishing village of La Boquilla, a short drive over the sand from Cartagena's airport, I watched local fishermen row out to retrieve their nets while I ate a classic shore dinner: grilled red snapper steak, *patacones* (flattened, fried slices of green plantain), French fries, homemade hot sauce, and *arroz con coco y pasas,* coconut rice with raisins.

Roman de Zurek also lists *arroz con coco* with pumpkin, with cassava, with ripe plantains, with black-eyed peas, with shrimp, with cheese, with salt beef, *con coco aguado* (swimming in thick coconut milk), and most intriguing of all, *con coco frito.* This is a final refinement of coconut milk cookery whose only parallel known to me is a West Sumatran dish called *rendang,* in which water buffalo is cooked for a long time in highly spiced, thick coconut milk until the meat is coated with a dark brown residue of the sauce. For *arroz con coco frito* in Cartagena something similar happens. The coconut milk is boiled until it appears to caramelize and browned solid matter sinks to the bottom of the pan. Then the rice is added and cooked in the "fried" coconut milk, which has by then lost its whiteness and turned to a transparent oil.

For the itinerant gastroethnographer this is not only a treat, but food for thought. How did coconut milk come to preoccupy the cooks of Colombia's Caribbean coast? For that matter, how did coconut get there? Was it native to those shores? Did slaves bring viable coconuts, the world's largest seeds, from West Africa to their new homes in this hemisphere? In general, this is a good question without a good answer. In the enormously detailed *Perennial Edible Fruits of the Tropics* (USDA Agriculture Handbook No. 642, 1987), Franklin W. Martin et al.

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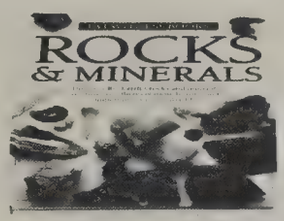

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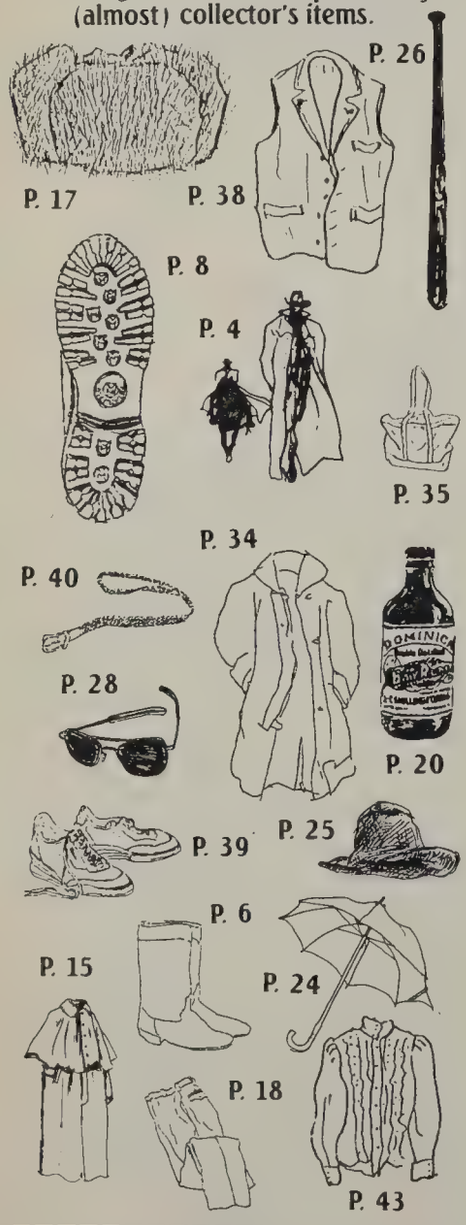

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give a terse, if not actually evasive, answer. They say, in a word, that the origin of *Cocos nucifera* is "pantropic."

That certainly describes the status quo. By one estimate, there are 600 million coconut palms distributed around the world, mostly in warm places. But where did this all start? The Indo-Pacific is an attractive choice, given the evidence: fossil coconuts in New Zealand, a rich panoply of coconut-specific parasites in Southeast Asia, and records of coconuts in India going back 3,000 years. In 1280, Marco Polo reported seeing coconuts in Sumatra and in India.

Vasco da Gama may be the first person to mention a non-Asian coconut. He sighted some in Mozambique in 1498, which leads to two speculations. First, that *C. nucifera* was brought to East Africa by Arab spice traders. Second, that the Portuguese introduced the plant to West Africa and Brazil after 1500, giving it its name, *coco,* from the Portuguese word for monkey, supposedly because of its eye pattern and brown furry skin.

But how did this invaluable seed get to the Caribbean and non-Portuguese South America, including Cartagena? Frederic Rosengarten, Jr., in *The Book of Edible Nuts,* states that early Spanish explorers found coconuts growing in Panama but that no indigenous people were eating them; and that the Spaniards introduced coconuts to their American empire in the early 1500s. There is also the theory of oceanic migration, in which prevailing currents transport viable coconuts across the Pacific and wash them up on idyllic New World beaches where they germinate under favoring suns.

None of this conjecture much impressed Thomas H. Everett. In his authoritative *Encyclopedia of Horticulture,* he takes a dim view of the oceanic migration theory, pointing to the paucity of recorded instances of "the successful establishment and spontaneous development of washed-up nuts into trees" and citing saline water in beach soil and the ravaging of young shoots by crabs as the chief deterrents to such a pattern of transmission. He also states that no "truly wild" coconut palm has ever been found anywhere and quotes the British palm authority E. J. H. Corner, who pronounced unequivocally that "there is no island or shore where its presence is not due directly or indirectly to its having been planted by man."

Well, then, which men brought *C. nucifera* to South America? For me, the evidence of culinary practice both in Colombia and in Northeast Brazil points most suggestively toward introduction by Spaniards and Portuguese as part of the process of colonization in an economy based on slaves imported from West Africa. Two facts are not in doubt. Both the

Arroz con Coco

Cartagenan coconut rice, adapted from a recipe in Teresita Roman de Zurek's *Cartagena de Indias en la Olla* (Gamma, 1987)

1 medium coconut (to produce 6 cups of coconut milk)
1 pound (2 cups) long-grain rice
1 tablespoon sugar
Salt

1. If you don't want to bother with extracting your own coconut milk, start with 6 cups of canned coconut milk (this is NOT the clear liquid that exists naturally in a ripe coconut and can be heard sloshing around inside it). To make coconut milk (*leche de coco*) from scratch, first open one or more of the eyes with a corkscrew and pour out the liquid. Reserve. Then split the coconut with a hammer. If the white meat does not pry easily out of the husk with a sharp, heavy knife, heat the pieces of unhusked coconut for a bit in a 300° oven. Then remove the meat and, using a vegetable peeler, trim off the thin brown skin on the husk side of the meat. Traditionally, the next step was to grate the coconut. In Colombia, there are special half-cylinder strainer-graters that make this fairly easy and somewhat safer to do. In North America, the best way is with the metal blade of a processor.
2. Take the processed coconut and squeeze the milk out of it over a medium strainer, by handfuls. When you have squeezed out as much as you can in this way (producing what is called the first milk or, sometimes, the thick milk), remoisten the squeezed, grated coconut with a cup or so of warm water and repeat the process. You may have to repeat it a third time until you have squeezed out 6 cups of milk.
3. Boil the coconut milk and reduce by half, to 3 cups, stirring frequently.
4. Add sugar, salt, and rice all at once. Reduce heat to a simmer and cook uncovered until no liquid is visible, stirring frequently all the while.
5. Cover, reduce heat as low as possible, and continue cooking until rice is cooked (in all cases that I experienced, this meant the soft side of *al dente,* but definitely not mushy). The rice will acquire a brown cast and an elegant flavor from the coconut milk.

Yield: 6 servings

Colombian Caribbean coast and Northeast Brazil were and are centers of transplanted West Africans. Both areas also continue to base much of their traditional cooking on coconut milk, a predilection not shared by contiguous centers of nonblack African heritage on the South American coast, even places of equally old colonization such as Venezuela. Furthermore, a notable number of the dishes of Cartagena and Northeast Brazil are almost exact equivalents of dishes popular in modern West Africa. Brazil's rice porridge cooked in coconut milk is called *acaca,* the name an identical dish gets in Benin and Nigeria. Cartagena-style coconut rice is common in West Africa and in Northeast Brazil.

This set of facts can be explained in several ways. Slaves with a common coconut-cooking heritage in West Africa were distributed among Spanish and Portuguese colonies and found coconuts already there. Or, these same slaves knew nothing of the coconut until they found it in the New World and experimented with its cultivation and use in cooking. Their fabulous success led eventually to the export of the coconut and coconut recipes to Africa, along with other useful American plants such as manioc and the peanut, which are now crucial to African agriculture and diet. Or perhaps coconut-wise slaves brought the coconut and their enthusiasm for it with them to the Americas, as they did okra and watermelon; and they continued to eat it in the old ways ever after.

This last scenario makes the most sense to me, especially if it includes Arab slavers as the coconut emissaries from East to West Africa at some point during the fifteenth century. If they were the bringers of coconut to Mozambique, why not elsewhere, when they were so much more established on the African continent so much earlier than the Portuguese or the Spaniards? This timetable allows for the establishment of mature trees in West Africa and for the creation of dishes (or were they too brought in by the Arabs?) before the American slave trade began.

But even if this theory is wrong, and the slaves in Cartagena and Bahia either applied earlier knowledge to indigenous coconuts or invented coconut dishes in the New World, we can certainly say thanks to them, as we eat our *arroz con coco,* for sponsoring, if not actually inventing, this and all the other delicious coconut dishes that now grace the tables of postcolonial South America's northern coasts.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

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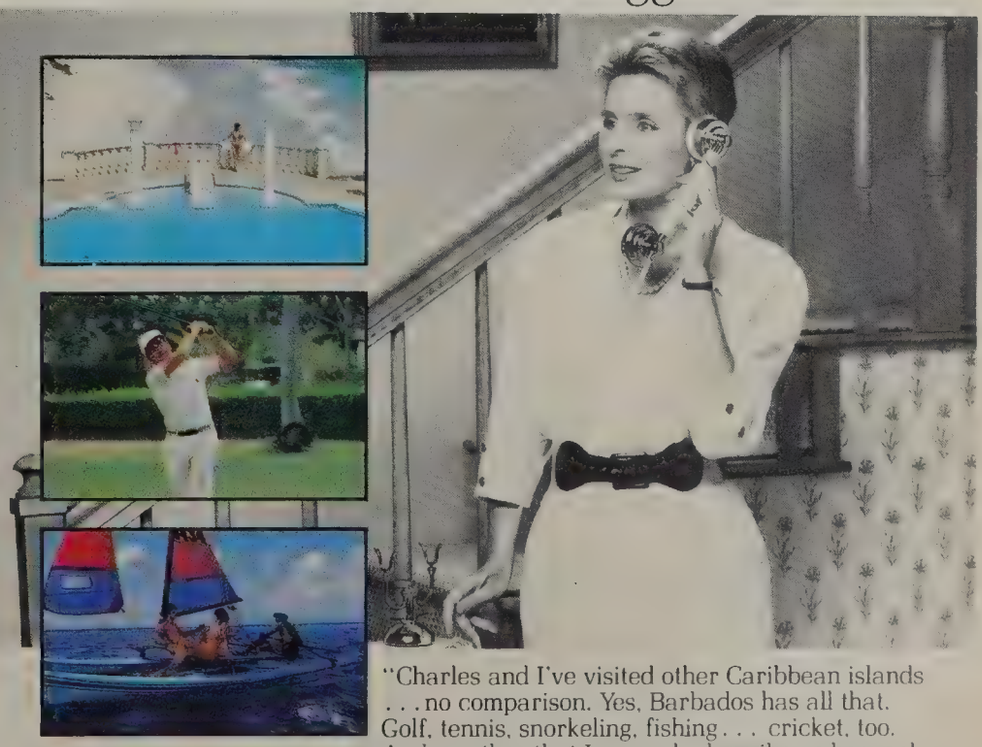

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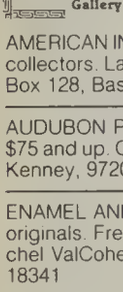

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A Kirtland's warbler nests on the ground in Michigan. Young jack pines growing in partly open areas, lower right, offer the type of nest protection the warblers need.
Larry West; National Audubon Society; Photo Researchers

Mack Lake, Michigan

by Robert H. Mohlenbrock

Many of my excursions take me through pristine forests, unplowed prairies, or scenic rock formations. The terrain around Michigan's finger-shaped Mack Lake does not offer these features, however. It is mostly flat, with scraggly jack pines and numerous areas of burned and cut trees. Yet this is one of the few places where the Kirtland's warbler nests and rears its young. Accordingly, signs attached to trees along the back roads that crisscross this part of the Huron National Forest notify the visitor that the interior is off-limits between May 1 and September 10. During this time, only ranger-led guided tours into the Mack Lake area are available.

Kirtland's warbler first came to the attention of scientists in the spring of 1851, when Charles Pease shot a migrating bird near Cleveland, Ohio. He gave it to his father-in-law, the noted naturalist Jared Kirtland, who in turn presented it to ornithologist Spencer F. Blair. The following year, Blair described the bird as being new to science, naming it in honor of Kirtland. After that, individual Kirtland's warblers were occasionally spotted during spring and fall migrations, but the species' breeding and wintering grounds long remained a mystery. The first wintering bird was found in January 1879, on Andros Island in the Bahamas. For the next twenty years, more than seventy specimens of Kirtland's warblers were collected in the Bahamas, but the place where they nested and spent their summers was still unknown.

Finally, more than a half century after the species' original description, a nesting bird was found in June 1903 near the Au Sable River in Michigan's Lower Peninsula. It was taken to ornithologist Norman A. Wood, who identified it as a Kirtland's warbler and, upon investigating, observed a nest of the birds for himself on July 8. From that time until now, all nests of this species have been found in the thirteen counties of jack pine habitat in the Lower Peninsula, with 90 percent of the nests located in the Au Sable River basin.

Lawrence Walkinshaw, an amateur ornithologist, has spent much of his free time from his occupation of dentistry studying Kirtland's warbler. He has noted that when the birds first arrive in Michigan in May, the males immediately select and defend their territories, even battling intruding males in midair by fluttering their breasts and feet against their opponents. Usually by June 1, the female bird has selected a mate, built a nest on the ground, and laid an average of five eggs. The young birds hatch out after an incu-

Bill Dyer; Photo Researchers

Mack Lake

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Joe LeMonnier

bation period of fourteen days, and nine or ten days later, now called fledglings, they leave the nest. Walkinshaw notes that the coloration of the fledglings is similar to that of an unopened jack pine cone, and the young birds resemble cones when they sit on the lower pine branches with their bills pointing upward.

Called the jack pine plains by the locals, the habitat favored by Kirtland's warbler has a poor, sandy soil that supports, in addition to jack pines, a variety of deciduous trees and a sparse collection of low-growing shrubs, grasses, sedges, and occasional wildflowers. The sand and the fallen pine needles create acidic soil especially suitable for members of the heath family: wild blueberries, bearberry, wintergreen, and trailing arbutus. Bracken fern and sweet fern are also plentiful (the latter has fernlike leaves but is actually a flowering plant). All the plant species that live here have to be able to withstand fire, drought and temperature extremes.

Because the bird's population appeared small and showed no sign of increasing concern for the survival of Kirtland's warbler arose as early as the 1940s, and in 1951, in commemoration of the 100th

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anniversary of the bird's discovery, an effort was made to find out how many of them actually summered in Michigan. Since male warblers arriving on the breeding grounds sing loudly and clearly, the census was taken by counting the number of singing males and doubling the total, on the assumption that each male attracted a mate. The 1951 census recorded 432 singing males, or an estimated breeding population of fewer than 900.

Apparently contributing to the species' survival problems are the birds' narrow nesting requirements. They nest only where there are stands of jack pine, building their nests on the ground under the trees, in association with a clump of grass or other vegetation. The nest consists of dead grasses, leaves, and small pieces of bark, lined with deer hairs, slender stalks of mosses, and fine porcupine quills. Almost always, the birds choose sites shaded and protected by low-hanging branches. As a result, they prefer stands of jack pine containing trees that are five to seven feet tall, or about eight years old. As jack pines mature beyond thirteen years and grow taller, the lower branches lose their needles, depriving the ground nests of shade and cover. By the time jack pines are twenty-one years old, the Kirtland's warblers will have nothing to do with them.

Based on the number of birds observed at the wintering grounds since the late nineteenth century, researchers have concluded that the Kirtland's warbler population was highest between 1880 and 1890. About that time, both lumbering and forest fires in the pinelands of Michigan contributed to regenerating young jack pines in the breeding grounds, apparently enhancing the birds' reproduction. In modern times, however, the suppression of forest fires has meant that many of the jack pine stands have aged, outgrowing their usefulness to the warblers.

To satisfy the warbler, the jack pine stands must not only contain sufficient young trees, but must also cover at least 80 acres and preferably as much as 200. Such stands usually have some deciduous trees, such as Hill's oak, red oak, pin cherry, and shadbush, mixed in, but if the proportion of such trees is too high, the Kirtland's warbler will reject the stand.

Furthermore, even though jack pines grow naturally from the maritime provinces of eastern Canada to the upper Yukon Valley in the Northwest Territories and south to Michigan's Lower Peninsula and central Wisconsin, only those in the southernmost part of the range seem to suit Kirtland's warbler. Forest growth in more northern areas apparently is too lush, while the stands in Michigan are ideal because the dry, nutrient-deficient soil limits the growth of the trees, as well as of the grasses and sedges beneath them, leaving a lot of open sandy areas in between. The soil—almost always a particular type known as Grayling sand—is also very porous, allowing water from heavy June rains to percolate down quickly without flooding the ground nests.

Given the small number of birds noted in the 1951 census, in 1957 the state of Michigan took measures to protect breeding habitat on state forestland. A census in 1961 recorded 502 singing males, a slight increase. Two years later, the U. S. Forest Service initiated its own plan, setting aside a 4,010-acre tract of jack pine forest in the Mack Lake area. Management areas were set up so that some jack pine stands would always be at the proper stage for the persnickety warbler. As stands grew too old for the birds, the trees would be harvested and new ones planted. In addition, the Forest Service cut and burned some old jack pine areas in the forest and replanted them with seedlings. And in 1966, when federal legislation was enacted to list and protect animal species threatened with extinction, Kirtland's warbler and thirty-three other species of birds were the first to make the list.

Despite these developments, by the 1971 census the number of singing male warblers had plunged to 201. Biologists

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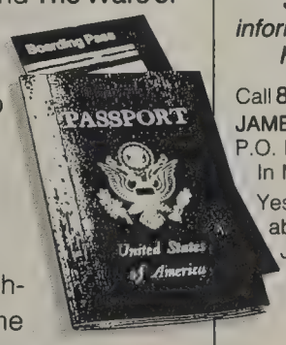

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then decided to attack another problem that affected the success of nesting, one that had been noted in the 1920s: brown-headed cowbirds parasitize the nests by laying their own eggs in them, often destroying some of the Kirtland's warbler eggs in the process. To combat this problem, cowbirds were trapped in the jack pine plains of Michigan and destroyed. More than 50,000 have been killed since 1972, and the threat they pose is now apparently under control.

A recovery team was also organized in 1975 to oversee the measures taken to preserve Kirtland's warbler. This was facilitated by the strengthened Endangered Species Act of 1973, which makes funding available to carry out management programs and to assist federal and state

Ron Austing; Photo Researchers

agencies in coordinating their efforts.

Ever since the alarming decline noted in 1971, a census has been taken each summer. The number of singing males appears to have stabilized, with a low of 167 reported in both 1974 and 1987 and a high of 243 in 1980. The total for 1989 was 212. At this point, observers believe that more than enough suitable habitat is available and that the population should eventually increase.

Even so, the management plan for the warbler's breeding grounds may not be enough to insure the preservation of the species. Since 1972, 800 to 900 warblers have gone south each fall, exiting the United States along the coast of the Carolinas before reaching their wintering grounds in the Caribbean, but only about 400 return to Michigan in June. Something must be happening to the birds during the spring and fall migrations or at the wintering grounds, which include Grand Turk Island, South Caicos Island, and Hispaniola, in addition to the Bahamas. Little is known about the fate of the birds during those times. Hurricanes, drought, or pesticides may destroy a few birds during migration, but hazards at the wintering grounds, where they spend up to eight months living amid shrubby, desertlike vegetation, probably take the greatest toll.

"This Land" highlights the biological phenomena of the 154 U. S. national forests. Robert H. Mohlenbrock is Distinguished Professor of Botany at Southern Illinois University at Carbondale.

Hatched in a warbler nest, a cowbird baby, left, demands sustenance.

LONE SAILOR

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Images of Feathers and Flight

by Michael Harwood

Let us now praise men and women whose vision and imagination expand, not shrink, as they grow older. Theodore Cross, a scholar specializing in the economic history of blacks in the United States, author of *Black Capitalism* and other books, founder and editor of a magazine of business ethics and responsibility, lecturer on law and minority economics, began fifteen years ago at the age of fifty to photograph—of all things—birds. The hobby transformed his life and, he says, glorified his passage into the inevitable infirmities of age. Studying and photographing birds, he writes in his brief introduction to this collection of bird photographs, "are superb ways of keeping one's

(Text continues on page 104)

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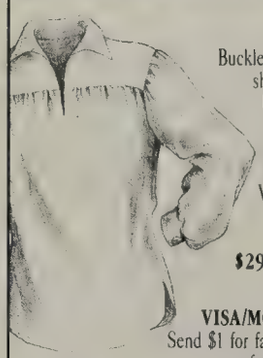

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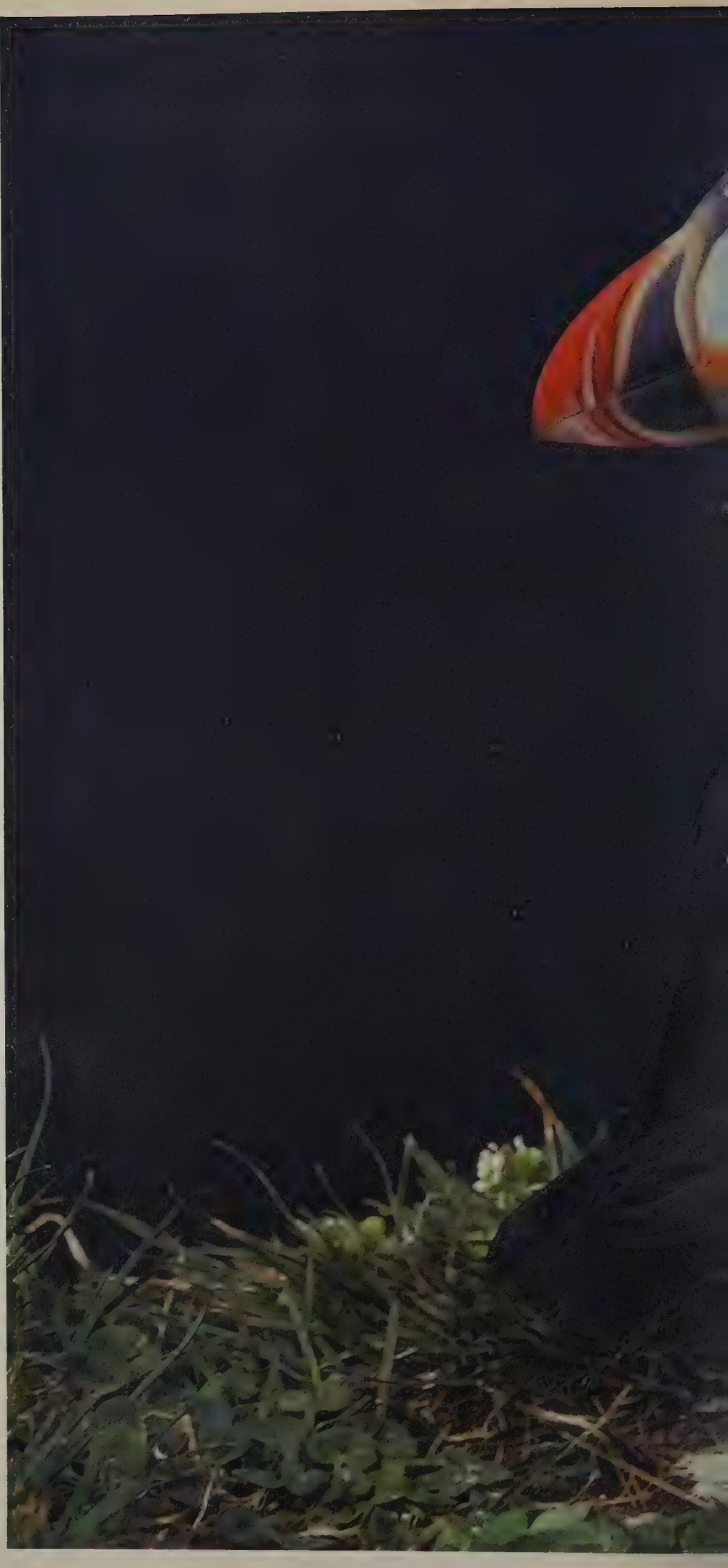

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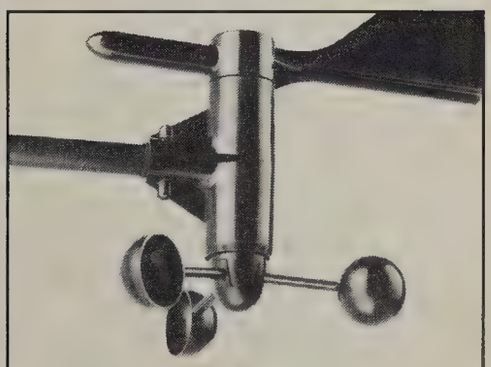

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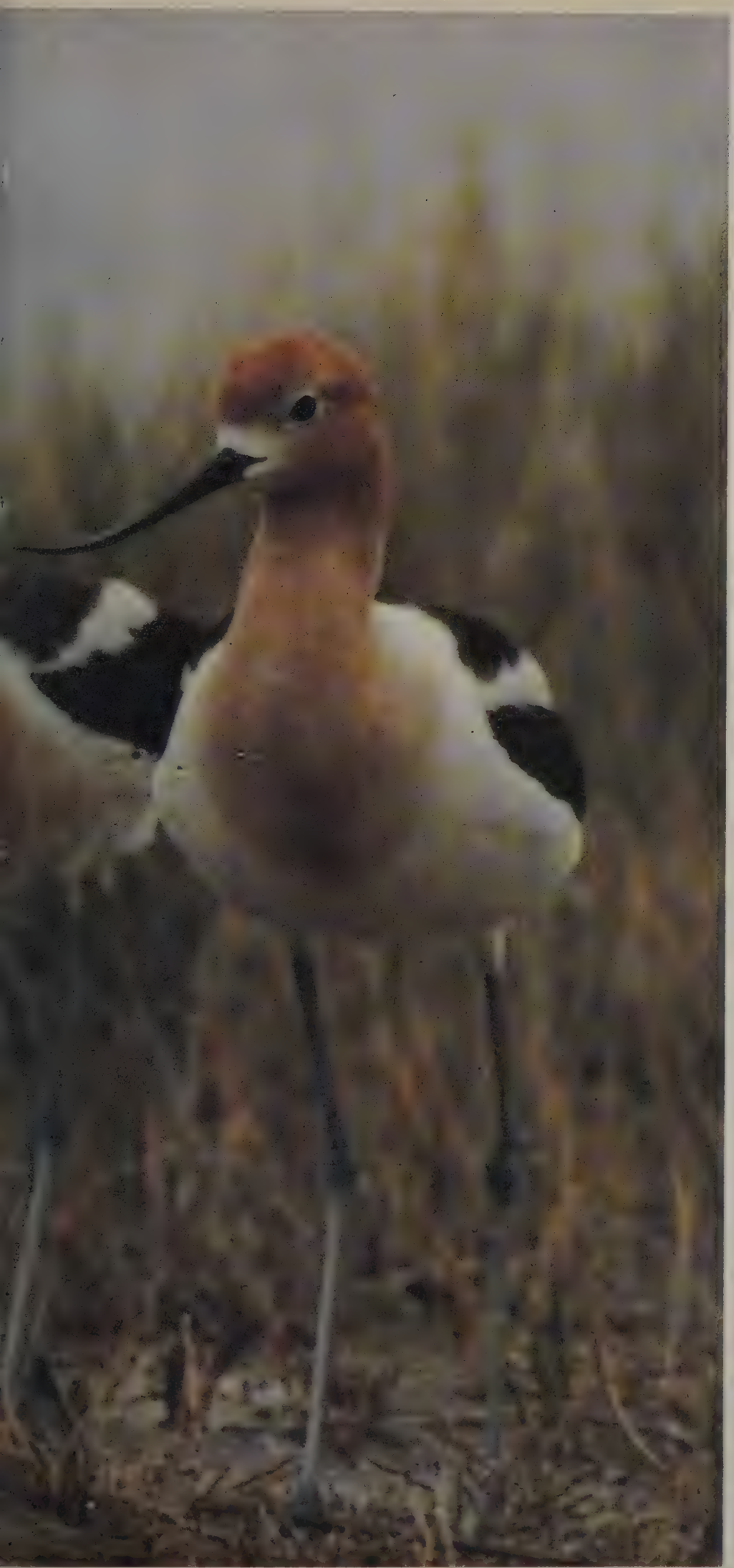

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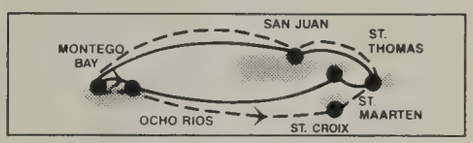

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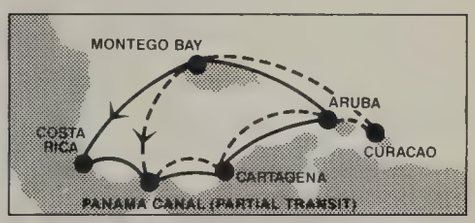

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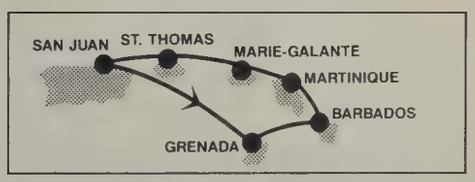

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mind off one's own mortality and staying very much alive . . . . When I was younger I struggled to find answers to some of the most vexing social problems of our time. Now . . . I sometimes think I would rather take a truly great photograph of a red-tailed tropicbird than find the truth about the higher meaning of life."

This man of habitual letters shows admirable restraint here, limiting his literary contributions to three paragraphs of pref-

---

BIRDS OF THE SEA, SHORE AND TUNDRA, by Theodore Cross. *Weidenfeld & Nicolson, $65.00; unpaged, illus.*

---

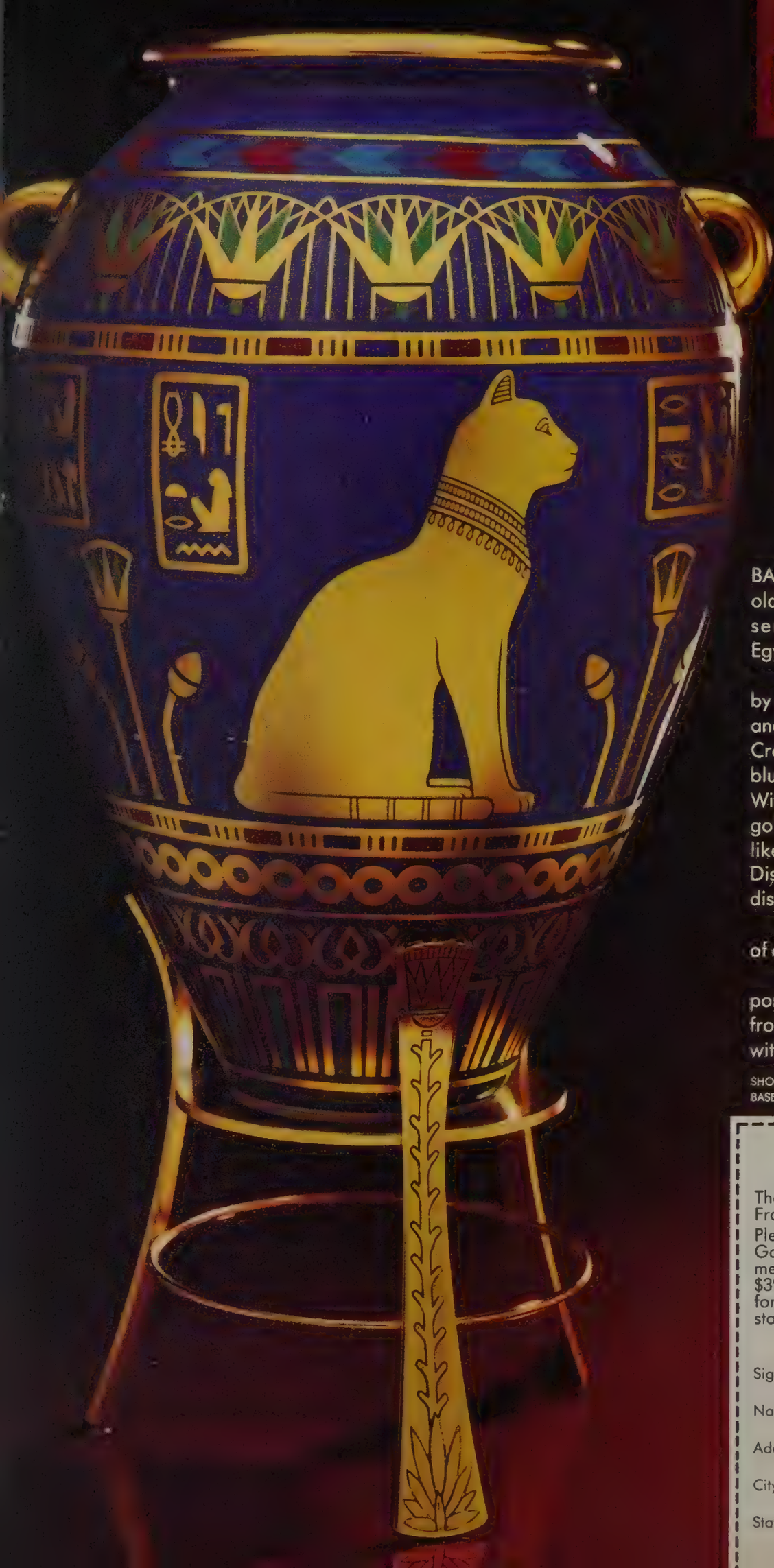
atory text and some short captions. Mostly he lets the photographs speak for themselves, which they do with an eloquence strongly suggesting that the truth about the higher meaning of life may in fact be found in a great photograph of a red-tailed tropicbird—or egret or stork or spoonbill.

All but a handful of the photographs in this collection are of birds one associates mostly with watery habitats. They include long-legged waders, oceanic wanderers such as boobies and tropicbirds, waterfowl, plovers, sandpipers, terns. Cross's approach to his subjects varies. Some of the photos are bird portraits in the classic sense, where the bird is shown in a subdued pose and in a frictionless setting that doesn't compete with the bird for attention. But he is more attracted to subtle complexities of shadow, light, reflection, and camouflage; to birds in stunning places or against abstract backgrounds, in striking poses or engaged in activities that take the observer by surprise.

To help organize my review I started to make a list of the photographs to which I am particularly partial, but I soon realized that the list would be so long as to be useless and that the descriptions I might write of particular photographs would be pale compared with the photographs themselves. Not that the book maintains super high quality throughout. If I ha edited the collection, I would have dis pensed with at least 10 percent of th photographs for the sake of the total im pact. A few are repetitious. A few aren't a sharp as they ought to be. And a few strik me as being compositionally or spirituall run-of-the-mill. But any moderatel knowledgeable, opinionated observer wil have nits to pick about any collection thi size—more than a dozen dozen works o art. Taken all in all, Cross demonstrates a extraordinary eye (and shutter-finger re flex) for the excitement and beauty o birds, and this is a first-rate production.

Michael Harwood, environmental jour nalist and natural historian, is the autho of The View from Hawk Mountain *an* The View from Great Gull, *among othe books. He and his wife, Mary Durant wrote* On the Road with John James Au dubon, *for which they were awarded th John Burroughs Medal.*

American egret



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Early Warning for Photographers

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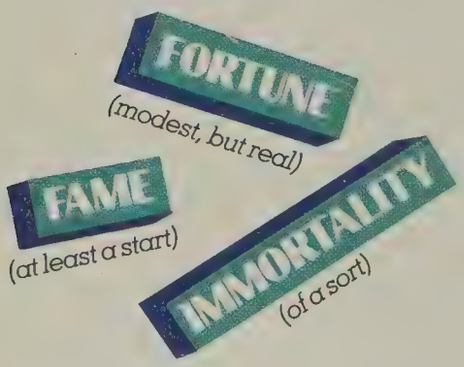

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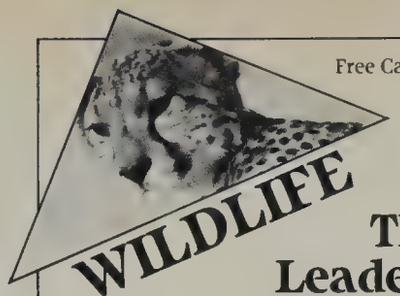
Exhibited at the American Museum of Natural History

For photographers who read the fine print (everyone should, but many don't, so you already have an advantage in this competition), here are some guidelines: Along with a best-of-show Grand Prize, *Natural History* will award three First Prizes and a slew of Honorable Mentions in three major categories: (1) Wildlife; (2) Landscape; (3) The Human Family. These categories are broad enough to accommodate almost any photograph, so winning will depend on a good eye, imagination, technical competence, and a bit of luck. In addition, Special Awards will be given in three unusual categories that will require some thinking and perhaps planning on the part of the photographer: (1) A Sequence in Nature; (2) Human Impact on the Biosphere; (3) Humor. We tossed in the last category to lighten the job of the judges and to remind all those serious nature photographers that even heavy-duty competitions such as this one have room for a smile.

Deadline for Entries: MARCH 1, 1990

(can't say you weren't forewarned)

Complete rules and entry forms will be published in *Natural History* when we get closer to the deadline.



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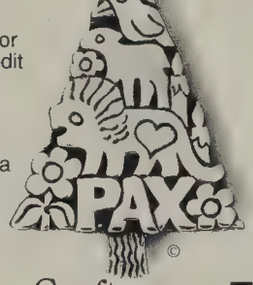

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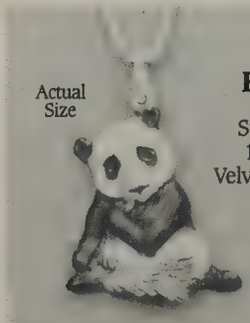

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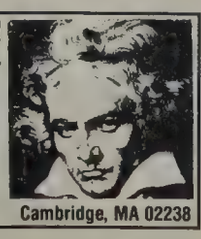

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At the American Museum

A Wing For the Birds

The Whitney Wing of the American Museum of Natural History, housing specimens of 99 percent of all known bird species, is one of the world's great ornithological centers. This month the Museum celebrates the wing's 50th anniversary with special exhibitions, events, and programs. The Audubon Gallery, which has rarely been opened to the public, will be open for viewing on the weekends of October 14–15 and 21–22. The gallery contains masterpieces of bird art by two generations of Audubons, Louis Agassiz Fuertes, Joseph Wolf, and others. In the Akeley Gallery, Francis Lee Jacques's oil paintings of oceanic birds of South America, including albatrosses, penguins, and petrels, will be on exhibit beginning October 6. The Hall of Oceanic Birds will have two special exhibitions from October 6 to 22. In "Bringing Art to Life," a diorama of Peru's Guano Islands will be opened up, allowing volunteers to demonstrate how birds are mounted and diorama backgrounds fabricated. "A New Wing for Birds" will focus on the history of the Whitney collection as an exhibition and research facility. On Wednesday, October 18, Ernst Mayr, the first Whitney and Rothschild Curator of Birds, will give a free lecture on the original Whitney expeditions, including the decade-long Whitney South Sea Expedition, and offer reminiscences of early bird studies at the Museum. As part of the same program, *Natural History* columnist Jared Diamond will speak on contemporary bird research in Melanesia. Among the many other events in observation of the anniversary will be special bird walks, a bird film festival, origami demonstrations, a library exhibition, and a special members' evening. More information on the Whitney 50th anniversary events can be obtained by calling (212) 769-5000.

Brain Size and the Evolution of Mind

At 6:00 P.M. on Tuesday, October 10, in the Kaufmann Theater, Harry J. Jerison, professor of biobehavioral sciences in the Department of Psychiatry and Biobehavioral Sciences in the Medical School at UCLA, will give the fifty-ninth James Arthur Lecture on the Evolution of the Human Brain. Jerison's subject is "Brain Size and the Evolution of Mind." The lec-

ture will focus on "encephalization," the evolution of brain structures related to "higher" mental functions. In addition, Jerison will discuss encephalization in fossils and living species as an index to the evolution of intelligence in mammals and will offer speculation on hominid encephalization, which is usually associated with the evolution of the capacity for language. For more information, call (212) 769-5375.

Caribbean Month

October is *Caribbean Month* at the Leonhardt People Center.

October 7–8: Jamaica is the focus with programs of dub poetry (poems set to reggae) and traditional music.
October 14–15: Trinidad is highlighted with demonstrations on the art of carnival costume design and on the making, tuning, and playing of steel drums.
October 21–22: Puerto Rico is featured this weekend, with poetry, folk music, and a slide-illustrated talk on cuisine.
October 28–29: Programs this weekend will include Dominican syncretic music, Taino Indian myths and legends, and traditional orisa practices.

There will also be several concerts. Yomo Toro, master of the electric *cuatro,* brings his "funky jibaro" music, blending traditional Puerto Rican folk music with everything from bluegrass to swing, to the Main Auditorium on Wednesday, October 4, at 7:30 P.M. Patakin will play music derived from Afro-Cuban rumba and santeria rites in the Kaufmann Theater at 2:00 and 4:00 P.M. on Saturday, October 14. Moods Pangroove, a champion steel band from Trinidad and Tobago, will play soca and calypso music in the Main Auditorium at 7:30 P.M. on Wednesday, October 25; and the award-winning Louines Louinis Haitian Dance Theater will perform in the Kaufmann Theater at 2:00 and 4:00 P.M. on Saturday, October 28. Short films will also be shown each weekend. All programs are free and open to the public. For a full schedule of events, call (212) 769-5315.

These events take place at the American Museum of Natural History, located on Central Park West at 79th Street in New York City. For more information about the Museum, call (212) 769-5100.

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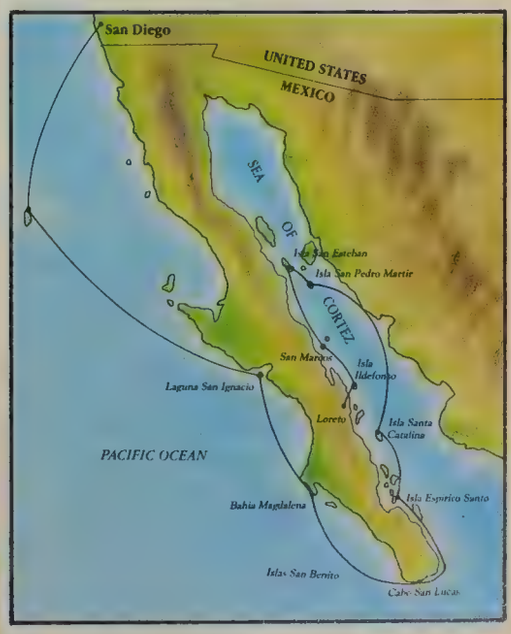

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Follow the Moon

by Thomas D. Nicholson

The moon passes Saturn, Uranus, and Neptune in less than sixteen hours on October 6 and 7. Brilliant Venus is below this scene, but because of its low altitude, it needs a relatively unobstructed southwestern horizon to be seen. Saturn is less bright than Venus, but because it is higher in the south-southwest after dusk, it is easier to see. Uranus and Neptune are near Saturn but cannot be seen without optical aid. All four planets are above the western horizon after sundown this month.

On the 7th the moon also passes Vesta, which became the fourth known asteroid when it was spotted in 1807. Although Ceres, which is 620 miles in diameter, is the largest asteroid known, Vesta, which is 330 miles in diameter, is the only one bright enough to be seen with the unaided eye when conditions are right. Vesta appears brighter because of its better reflectance and because it approaches closer to the sun than the other major asteroids.

Since the beginning of the last century, astronomers have found nearly 4,000 asteroids orbiting the sun, most between Mars and Jupiter. In recent years a watch for fast-moving asteroids (which indicates that they are close to us) has been maintained at several observatories. Earlier this year, astronomers tracking asteroids at the Lowell Observatory were surprised by a small, faint object speeding away from earth. When the orbit of the object, now known as 1989 FC, was calculated at the Minor Planet Center in Cambridge, Massachusetts, they found that it had passed within 430,000 miles of earth on March 22. That's less than twice the distance to the moon! Although this was comfortably far enough away from the earth not to have endangered us, in relation to the immense distances separating the planets (tens and hundreds of millions of miles), it seemed like a "near miss."

Events in the calendar below are given in local time unless otherwise indicated.

October 1: The thin, early evening crescent moon is low in the southwest tonight, at apogee (farthest from the earth). Brilliant Venus gleams like a beacon in the southwest, where it remains for the rest of the year as it grows more prominent.

October 2: It's Saturn's turn (following Uranus last month) to reach its most southerly position in our sky. Find the planet in Sagittarius, low in the southwest during early evening and resembling a bright yellowish star.

October 3: Mercury's westerly (retrograde) motion ends, and its morning sky visibility improves for the next week or so.

October 4: The waxing crescent moon is near reddish Antares this evening.

October 5: After passing Antares at midnight this morning, the crescent moon appears to its left this evening.

October 6–7: The moon passes through Sagittarius' Teapot, passing Uranus, Saturn, and Neptune within sixteen hours. Vesta, a 7th-magnitude "minor" planet, or asteroid, is occulted by the moon as it goes by. Saturn, the only planet of the group visible without a telescope, is above and to the right of the moon on the 7th, when the moon reaches first quarter at 8:52 P.M., EDT. Venus is well to the right of both the moon and Saturn.

October 8–10: The stars of Capricornus are above and to the left of Saturn. The waxing gibbous moon, passing through this constellation, does not hide its brighter stars. On the 10th, Mercury reaches its greatest morning elongation (only 18° to the sun's right, it is not the best), but the planet begins rising steeply into the morning sky, one and a half hours before the sun. Mercury is brightest before sunrise several days before the 10th.

October 11–13: The gibbous moo passes below the Square of Pegasu Markab and Scheat, above the moon the 11th, mark the west side of t Square; Algenib and Alpheratz, on t east side, are lined up with the moon the 13th.

October 14: Full moon, at 4:32 P.M EDT, is in Pisces. This evening the moo is also at perigee (nearest the earth), so t full moon will appear larger than usua The October full moon has traditional been called the hunter's moon, since olden times it helped nighttime hunte lay in provisions for the coming winter.

October 15: Hamal and Sheratan, t brighter stars of Aries, are above t moon.

October 17: The waning gibbous moo rising after sundown in Taurus, pass close to the Pleiades cluster in the mor ing. Venus is passing Scorpius' Antares the evening sky.

October 19–21: The brilliant planet J piter, the moon, and Gemini's Pollux a Castor rise before 11:00 P.M., EDT, on t 19th. The Orionid meteor shower is th year's second best, almost rivaling A gust's Perseids. A maximum of thirty or per hour can be seen on the 21st, falling twenty or more the night before and aft Last-quarter moon, at 9:19 A.M., EDT, the 20th, is not bright enough to interfe with meteor watching.

October 27: Sharp eyes may spot t heliacal predawn rising of the thin cre cent moon this morning just before t growing light hides it.

October 28: The moon is farthest fro the earth (apogee) for the second time October. Jupiter begins its retrograd swing, signaling its coming cycle as evening object, even though it is st largely a morning star.

October 29: Daylight time ends at 2:

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The fall Sky Map shows the sky for October, November, and December from 40° north latitude at the hours given below. To use the map, hold it vertically in front of you with south (S) at the bottom and match the lower half with the stars yo see when you face south. As you face other directions, turn the map to bring th corresponding compass direction to th bottom. The stars move continuous westward during the night. By morni (before dawn), those on the western ha of the map will have set, those on th eastern half will have moved into th west, and new stars (those of the wint

evenings) will have risen in the east. The map represents the sky at about 1:30 A.M. on October 1; 12:30 A.M. on October 15; 11:30 P.M. on November 1; 10:30 P.M. on November 15; 9:30 P.M. on December 1; 8:30 P.M. on December 15; and 7:30 P.M. on January 1. Add one hour for daylight-saving time when necessary. The map can be used for an hour or more before and after the times given.

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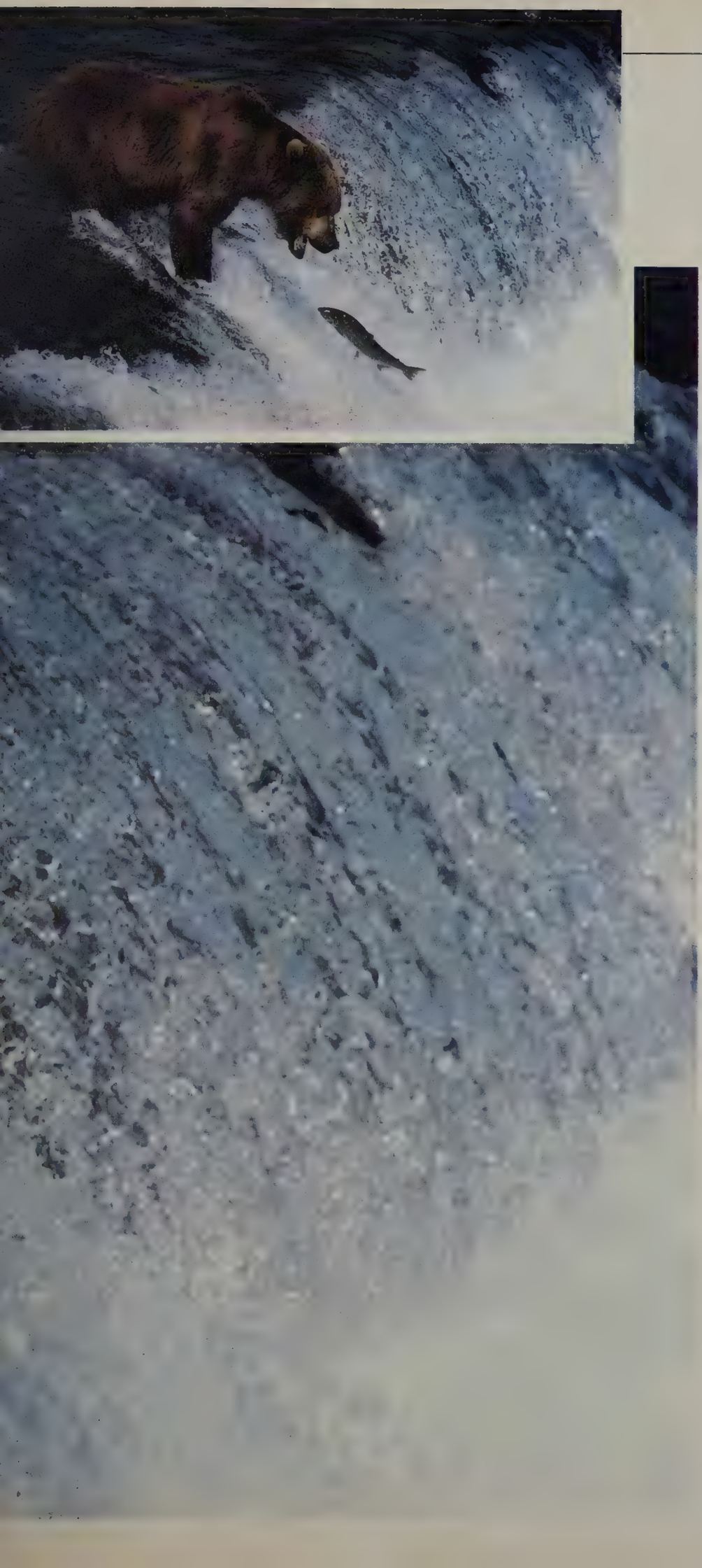

Leap of Faith

The sockeye salmon that annually navigate Brooks Falls in Alaska's Katmai National Park are prodigious leapers, to the chagrin of even the most strategically stationed angler. Each summer, hundreds of Katmai's brown bears forgo their solitary ways and, after much bullying of their fellows, stake out fishing spots along rivers. There they batten on salmon driven upstream by unshakable instinct. After a few years at sea, salmon undertake a grueling odyssey to the freshwater tributaries of their birth, where they spawn and then die by the millions. Those that fail to finish the course will sustain not only the fishing bears but also the scavenging foxes, gulls, and eagles that feed on the plentiful scraps.

Sixty years ago, before the plunder of immature salmon by drift-net operations in the Pacific, before hundreds of miles of Alaska's coast were oiled, wildlife writer Ernest Thompson Seton celebrated the sheer abundance of the Pacific salmon run, the "big feast of the Brown-bear's life. Now the salmon commence to run, and the Bears gather and gorge themselves where the flooded streams are swarming with fish that are mad to spawn."—*J. R.*

Photographs by Jeff Foott

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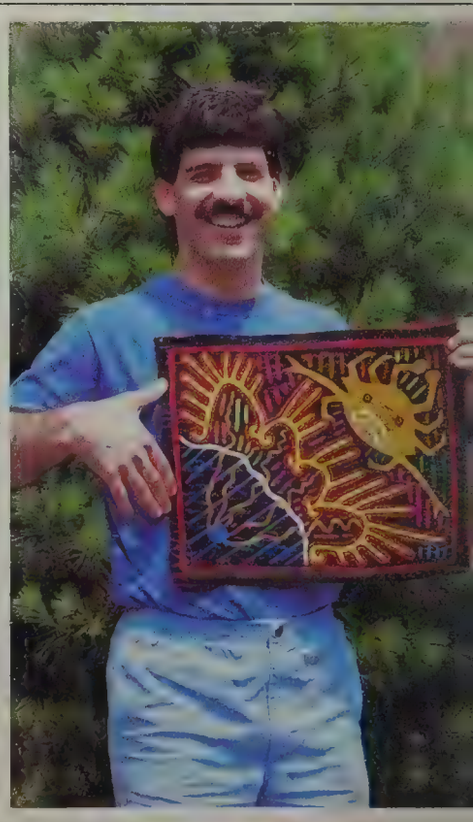
Authors

As a child growing up in a suburb in Virginia, **Lucia Jacobs** (page 40) set up a squirrel feeding station outside her bedroom window. Her interest turned professional when, years later, she was in need of a topic for her doctoral dissertation and found that no one knew if squirrels could remember where they buried their nuts. Jacobs has recently turned her attention to learning in other rodents. Currently a postdoctoral fellow at the University of Pittsburgh, she is investigating the different ways kangaroo rat and pocket mice forage for food in their desert environment. While in Pittsburgh, she will also be studying how male and female voles differ in their spatial learning abilities. A diverting collection of anecdotes, gossip, and history about squirrels, especially for readers living in New York City, is Eugene Kinkead's *Squirrel Book* (New York: E. P. Dutton, 1980). The most current comprehensive reference on squirrels is perhaps John Gurnell's *The Natural History of Squirrels* (New York: Facts on File Publications, 1987).



Intrigued by **Matthew Grober**'s studies of luminescent brittle stars (page 72), the Kuna Indians on the Panamanian island where the scientist was doing his research presented him with a special *mola*. The textile depicts a reef and a brittle star, surrounded by a halo of light. In an upper corner, a swimming crab, which has just encountered the brittle star, looks quite displeased. Grober's interest in luminescent marine invertebrates began when he was an undergraduate in California. Now a postdoctoral fellow in the neurobiology and behavior section of the Department of Biology at Cornell University, he is also studying the neurological changes that accompany sex reversals in fish, a common occurrence among many reef species. For readers with further interest in why some animals glow, Grober recommends a book edited by Peter Herring, *Bioluminescence in Action* (New York: Academic Press, 1978).

Having spent childhood summers on the Navajo reservation in Arizona, **Geoffrey G. Pope** (page 48) became fascinated with the past and archeology at an early age. As a result of a sojourn on Taiwan, he decided to focus on Asian paleoanthropology, and upon entering graduate school at the University of California, Berkeley, he began translating and synthesizing numerous Chinese books and journals on the subject. Pope soon determined he would do his fieldwork in Thailand, a land intermediate between two important fossil areas, China and Java. He has also done research in China and Indonesia. Formerly a Fulbright Lecturer at the University of Indonesia, Pope is currently an assistant professor of anthropology at the University of Illinois, Urbana-Champaign. For additional reading he recommends "The Lower Palaeolithic Cultures of Southern and Eastern Asia," by Hallam L. Movius, *Transactions of the American Philosophical Society,* vol. 38, pt. 4 (March 1949); *Eugène Dubois and the Ape-Man from Java,* by Bert Theunissen (Norwell: Kluwer Academic Publishers, 1988); *Prehistory of the Indo-Malaysia Archipelago,* by Peter Bellwood (New York: Academic Press, 1985); and *The International Forest Book,* by Mitchell Beazley (London: Simon and Schuster, 1981).

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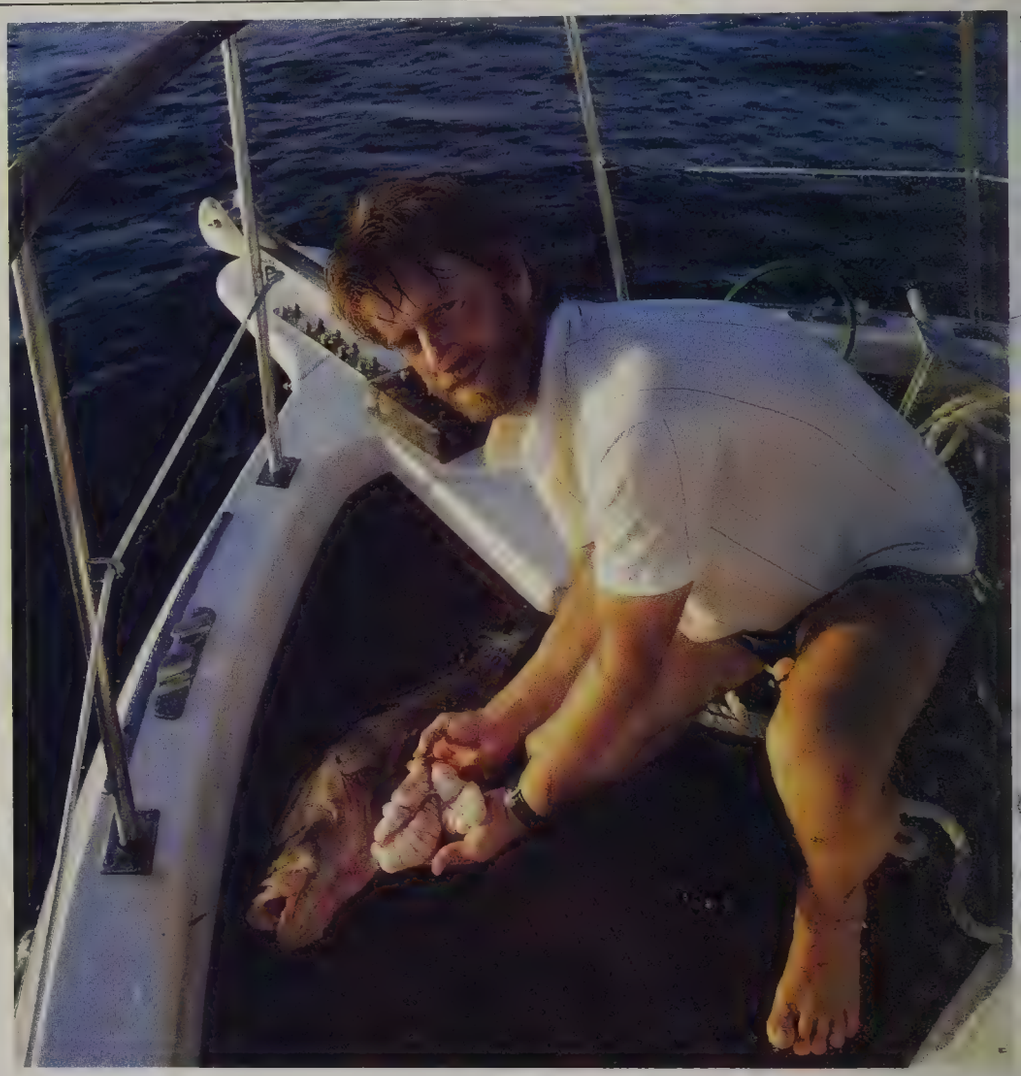
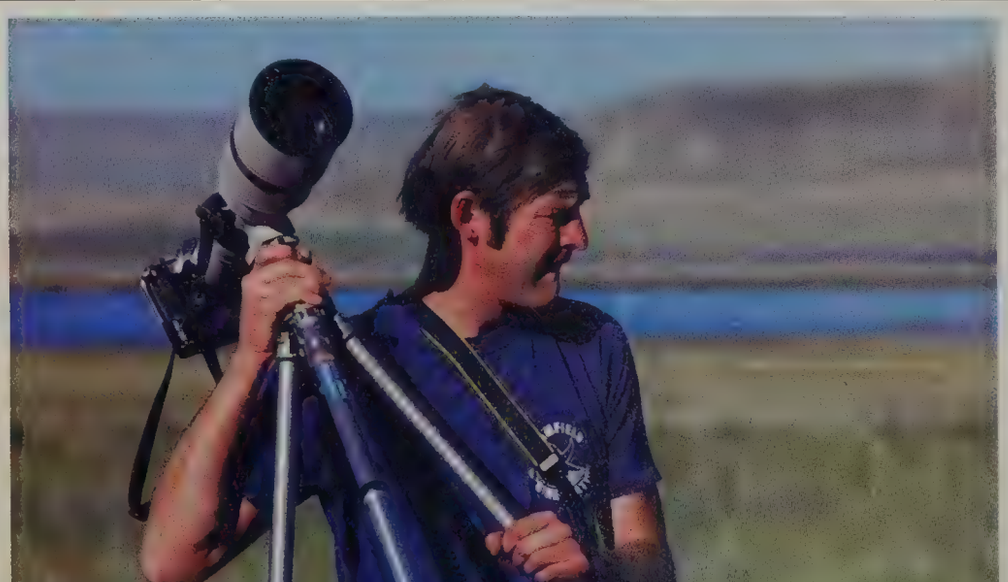
In 1974, as an undergraduate at Northern Illinois University, **Jacque Carter** (page 60) went to Belize for a field course on coral reef ecosystems. He enjoyed the course so much, he says, that he decided then and there to become an ichthyologist. Ten years later, after receiving his Ph.D., Carter returned to Belize, where he spent almost three years studying the effects of intensive fishing on Nassau groupers. Today he is an assistant professor of biology at the University of New England in Biddeford, Maine, as well as a research conservation fellow with the New York Zoological Society. In his latter position he continues to study the effects of commercial fishing on fish communities off the coast of Belize. "In heavily fished areas," Carter reports, "we've found an absence of large predatory fish. As a result, there is a shift in the balance of the fish community." One goal of the research, he says, is to determine the ecological consequences of the imbalance. For more about groupers and other tropical marine fish, Carter recommends *Reproduction in Reef Fishes,* by R. E. Thresher (Neptune City: TFH Publications, 1984), and *Words of the Lagoon,* by R. E. Johannes (Los Angeles: University of California Press, 1981).





To capture this month's "Natural Moment," nature photographer **Jeff Foott** (page 112) spent a week perched on a platform overlooking the salmon-filled waters of Brooks Falls in Alaska's Katmai National Park, patiently observing the comings and goings of hungry brown bears. Foott grew up in Berkeley, California, and lives in Jackson Hole, Wyoming. After receiving a degree in biology, he began doing research on the behavior of otters. But he found academic study "too confining." "I discovered I liked all kinds of animals," he says. "I was interested in birds and plants, too—not only otters." The pictures of the frustrated bear in this issue were shot with a Cannon camera fitted with a 400-mm f2.8 lens.

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NATURAL HISTORY

NOVEMBER 1989

COVER: *A Mars-sized body strikes the primordial earth. According to a new theory, the material blasted into orbit by such an impact coalesced to form the moon. Story on Page 68. Painting by William K. Hartmann.*

4 LETTERS

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Dark Side of the Shaman

14 THIS VIEW OF LIFE *Stephen Jay Gould*
The Creation Myths of Cooperstown

28 NATURE'S INFINITE BOOK *Jared Diamond*
Bittersweet Dreams of Glory

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Why were university-bred birds from Cornell more addleheaded than pigeons bred in nearby towns?

50 RETURN OF THE MIGHTY MUSKOX *Peter C. Lent*
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68 BIRTH OF THE MOON *Text and paintings by William K. Hartmann*
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78 LONE RANGER OF THE ROCKIES *Patricia H. Hayward and Gregory D. Hayward*
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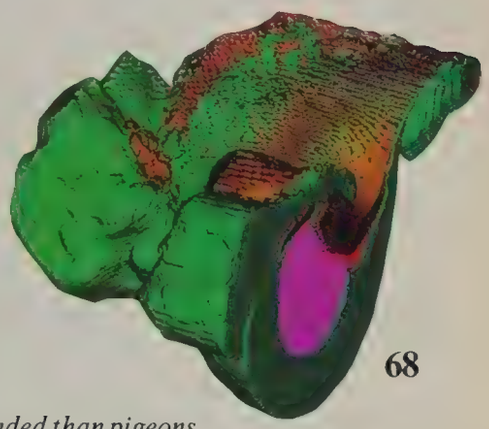

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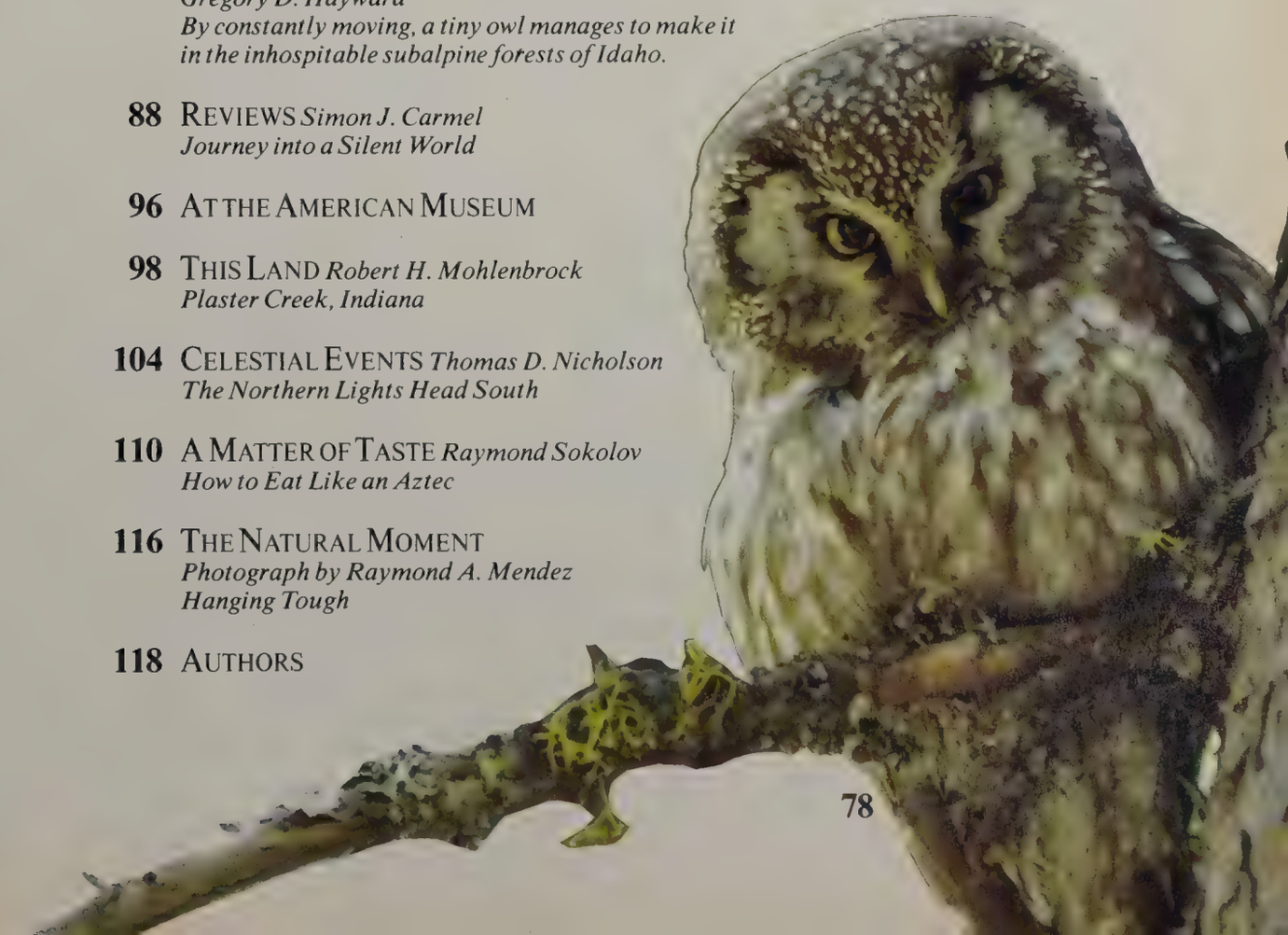

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CAT DEFENSE

I think William V. Dickinson ("Letters," September 1989) overstates the case when he says that "when we move onto a piece of ground with our pets, the native animals must move or die."

I've lived on the edge of a major city for sixteen years. There are more than twenty houses on my block, each with a resident dog or cat or both. Most of the cats roam free.

This summer I have seen in my yard chipmunks, cottontail rabbits, all too many gray squirrels, a red squirrel, white-footed mice, field mice, meadow voles, and (too big for cats, but not for dogs) raccoons. Two blocks away a piece of empty land supports several pocket gopher colonies. I have also seen, in my yard, English sparrows, starlings, grackles, redwings, cardinals, robins, several varieties of warbler, juncos, orioles, nuthatches, wrens, crows, and a bunch of other birds I don't know the names of.

In my observation, crows, blackbirds, and blue jays are greater enemies of other birds than are cats or dogs. Red-tailed hawks, great horned owls, and screech owls also hunt in my neighborhood. (I could, if I chose, be shopping at a Saks Fifth Avenue in less than half an hour.) Without some form of predation, we would be overrun with small animals.

It is true that there are fewer robins and orioles than there used to be, but I think that has more to do with rain forest clearance by a larger species than with cats.

L. T. SPARER
Minneapolis, Minnesota

POISONED BEHAVIOR

I want to correct a small mistake in Keith Clay's otherwise interesting and informative article ("Trespassers Will Be Poisoned," September 1989). He stated that ergot poisoning may have been responsible for strange behavior among suspected witches in the Salem Village witch trials. Linnda Caporael, in *Science* (192:21–26), and Mary Matossian, in *American Scientist* (70:355–57), provide evidence that the *accusers,* in Salem and elsewhere, were probably affected by ergot poisoning after they ate infected rye

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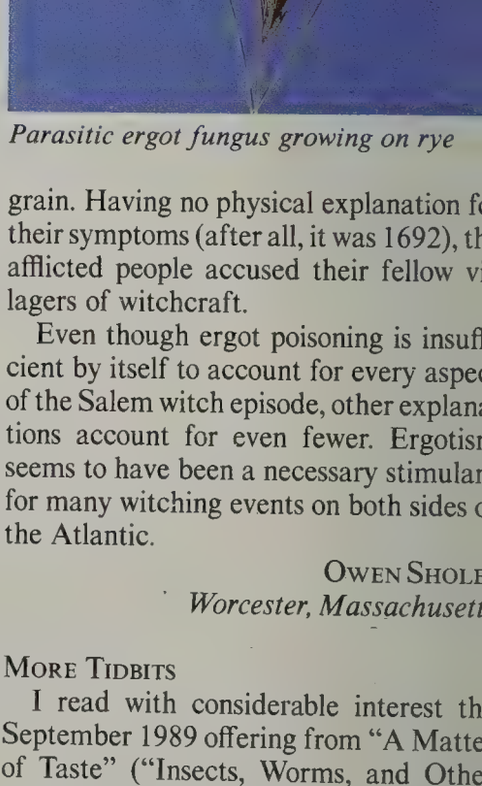

Parasitic ergot fungus growing on rye

grain. Having no physical explanation f their symptoms (after all, it was 1692), t afflicted people accused their fellow v lagers of witchcraft.

Even though ergot poisoning is insuf cient by itself to account for every aspe of the Salem witch episode, other explan tions account for even fewer. Ergotis seems to have been a necessary stimula for many witching events on both sides the Atlantic.

OWEN SHOL
Worcester, Massachuset

MORE TIDBITS

I read with considerable interest th September 1989 offering from "A Matte of Taste" ("Insects, Worms, and Othe Tidbits"). I feel obligated to add that M Sokolov neglected to mention a uniqu and noteworthy use of *gusanos,* the larva form of the butterfly that pollinates th maguey plant. As noted in the article, th sap of the maguey is used to produce sev eral alcoholic beverages, the most wel known being tequila. In the Mexican stat of Oaxaca, a tequilalike beverage know as *mezcal* is made from the maguey. Eac bottle of *mezcal* contains one or perhap two juicy *gusanos,* which add an inimita ble flavor and lie waiting at the bottom fo the lucky soul who draws the last draft Needless to say, the presence of *gusano* has given rise to a whole body of (western North American) folk wisdom concernin the singularly wonderful and evil qualitie of *mezcal.*

STEVE ROSENSTOCK
Fredonia, Arizon

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(Motion captured on Normal* film.)

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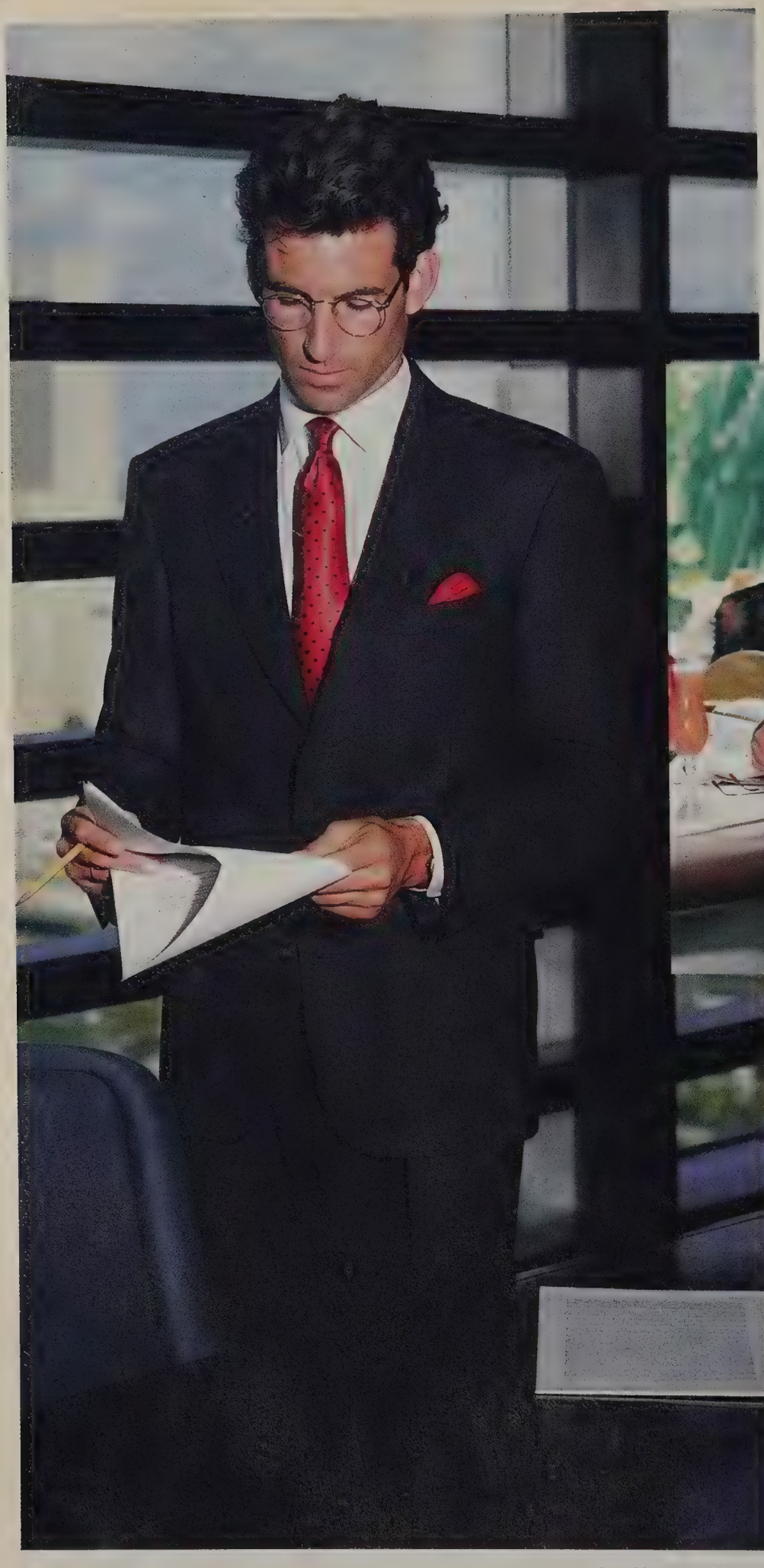

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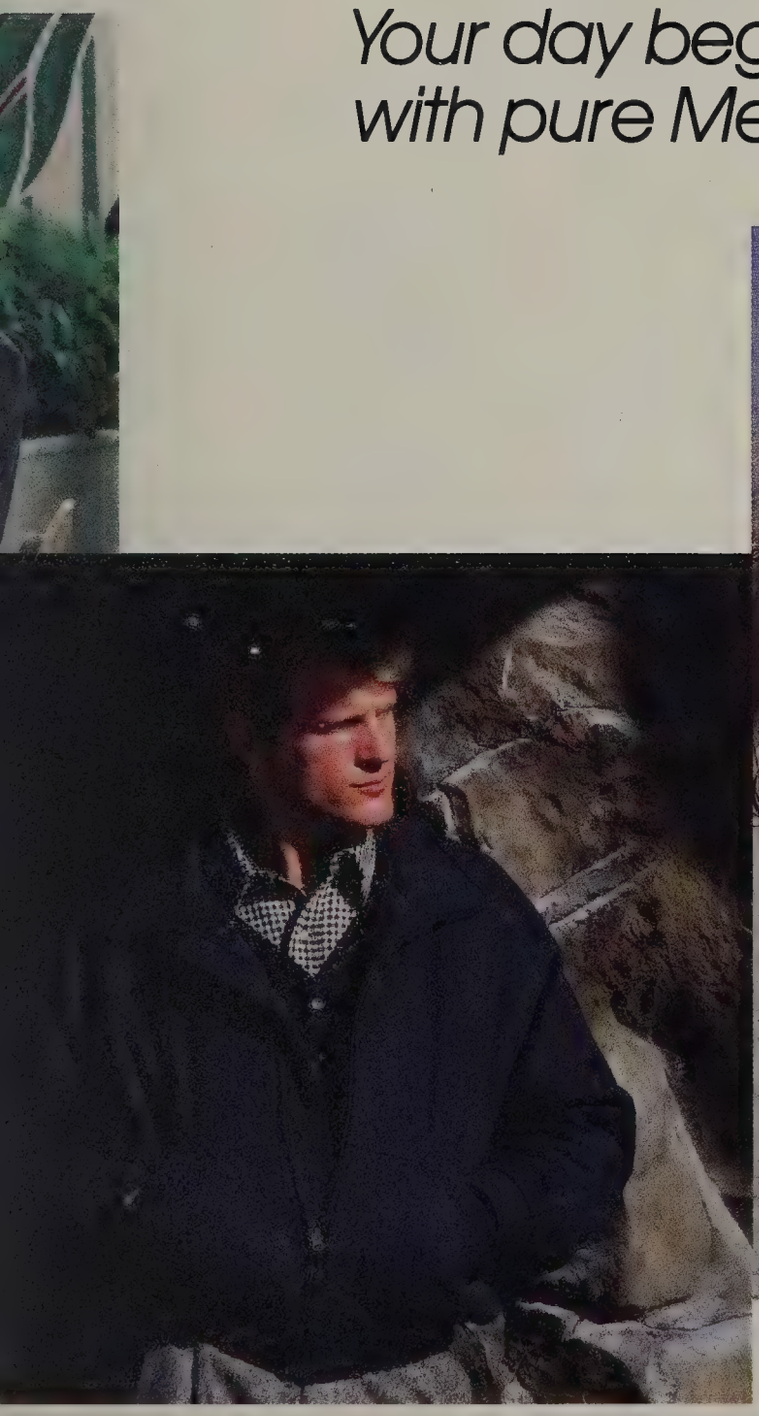

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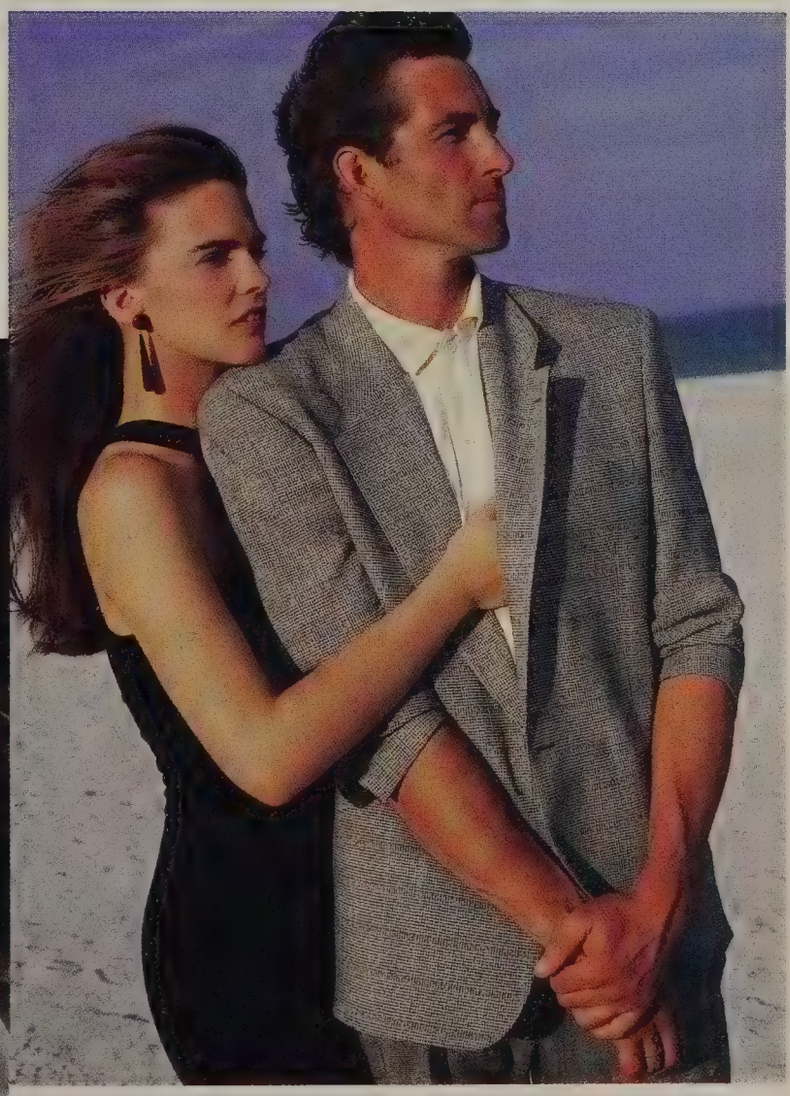

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Dark Side of the Shaman

The traditional healer's art has its perils

by Michael Fobes Brown

Santa Fe, New Mexico, is a stronghold of that eclectic mix of mysticism and folk medicine called "New Age" thought. The community bulletin board of the public library, just around the corner from the plaza and the venerable Palace of the Governors, serves as a central bazaar for spiritual guides advertising instruction in alternative healing methods. Many of these workshops—for example, classes in holistic massage and rebirthing—have their philosophical roots in the experiments of the 1960s. Others resist easy classification: What, I've wondered, is Etheric Body Healing and Light Body Work, designed to "resonate the light forces within our being"? For thirty-five dollars an hour, another expert offers consultations in "defense and removal of psychic attack." Most of the classes, however, teach the healing arts of non-Western or tribal peoples. Of particular interest to the New Agers of Santa Fe is the tradition known as shamanism.

Shamans, who are found in societies all over the world, are believed to communicate directly with spirits to heal people struck down by illness. Anthropologists are fond of reminding their students that shamanism, not prostitution, is the world's oldest profession. When, in my role as curious ethnographer, I've asked Santa Feans about their interest in this exotic form of healing, they have expressed their admiration for the beauty of the shamanistic tradition, the ability of shamans to "get in touch with their inner healing powers," and the superiority of spiritual treatments over the impersonal medical practice of our own society. Fifteen years ago, I would have sympathized with these romantic ideas. Two years of fieldwork in an Amazonian society, however, taught me that there is peril in the shaman's craft.

A man I shall call Yankush is a prominent shaman among the Aguaruna, a native people who make their home in the tropical forest of northeastern Peru. Once feared headhunters, the Aguaruna now direct their considerable energies to cultivating cash crops and protecting their lands from encroachment by settlers fleeing the poverty of Peru's highland and coastal regions.

Yankush is a vigorous, middle-aged man known for his nimble wit and ready laugh. Like every other able-bodied man in his village, Yankush works hard to feed his family by hunting, fishing, and helping his wife cultivate their fields. But when his kinfolk or friends fall ill, he takes on the role of *iwishín*—shaman—diagnosing the cause of the affliction and then, if possible, removing the source of the ailment from the patient's body.

In common with most peoples who preserve a lively shamanistic heritage, the Aguaruna believe that life-threatening illness is caused by sorcerers. Sorcerers are ordinary people who, driven by spite or envy, secretly introduce spirit darts into the bodies of their victims. If the dart isn't soon removed by a shaman, the victim dies. Often the shaman describes the dart as a piece of bone, a tiny thorn, a spider, or a blade of grass.

The Aguaruna do not regard sorcery as a quaint and colorful bit of traditional lore. It is attempted homicide, plain and simple. That the evidence of sorcery can only be seen by a shaman does not diminish the ordinary person's belief in the reality of the sorcerer's work, any more than our inability to see viruses with the naked eye leads us to question their existence. The Aguaruna insist that sorcerers, when discovered, must be executed for the go of society.

Shaman and sorcerer might see locked in a simple struggle of good agai evil, order against chaos, but things a not so straightforward. Shamans and s cerers gain their power from the sa source, both receiving spirit darts from trusted instructor. Because the darts tempt to return to their original own apprentice shamans and sorcerers mu induce them to remain in their bodies purifying themselves. They spend mont in jungle isolation, fasting and practici sexual abstinence. By wrestling with t terrifying apparitions that come to plag their dreams, they steel themselves fo life of spiritual struggle.

There the paths of sorcerer and sham divide. The sorcerer works in secret, usi spirit darts to inflict suffering on his e mies. The shaman operates in the pub eye and uses his own spirit darts to thwa the sorcerer's schemes of pain and u timely death. (I say "he," because to m knowledge all Aguaruna shamans a men. Occasionally, however, a woman accused of sorcery.) Yet because shama possess spirit darts, and with them t power to kill, the boundary between s cerer and shaman is sometimes indistin

The ambiguities of the shaman's r were brought home to me during a heali session I attended in Yankush's hou The patients were two women: Yan nuanch, who complained of pains in h stomach and throat, and Chapaik, w suffered discomfort in her back and low abdomen. Their illnesses did not seem l threatening, but they were persiste enough to raise fears that sorcery was the root of the women's misery.

As darkness fell upon us, the patie

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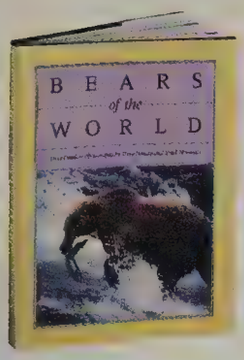

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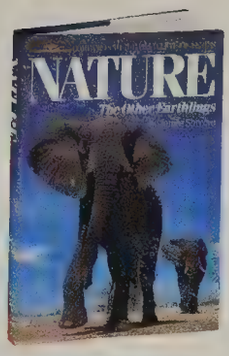

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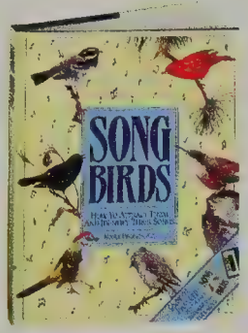

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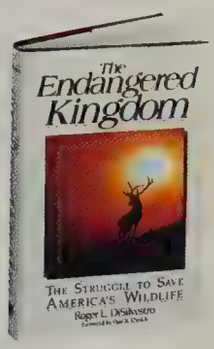

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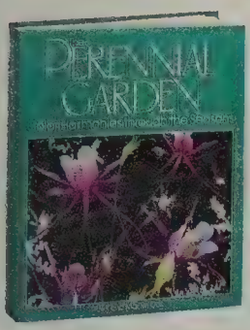

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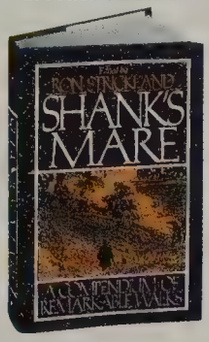

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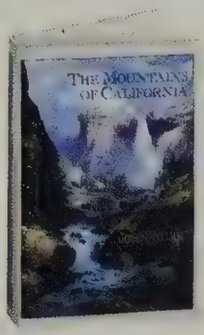

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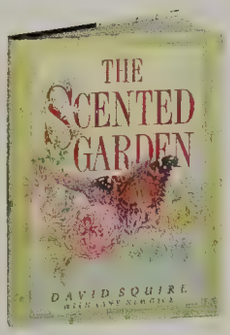

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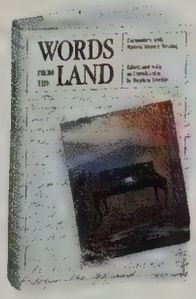

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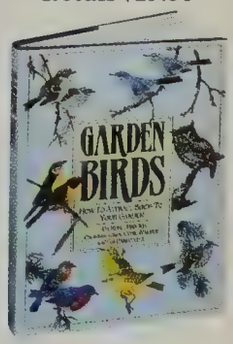

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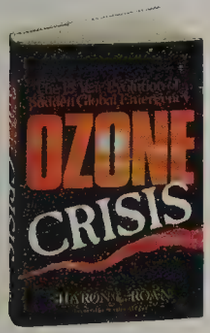

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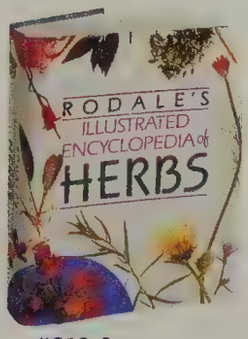

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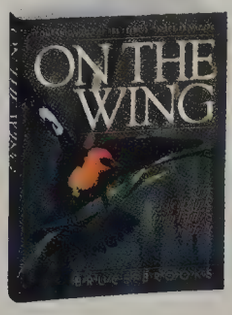

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and their kin waited for Yankush to enter into a trance induced by a bitter, hallucinogenic concoction he had taken just before sunset (it is made from a vine known as *ayahuasca*). While the visitors exchanged gossip and small talk, Yankush sat facing the wall of his house, whistling healing songs and waving a bundle of leaves that served as a fan and soft rattle. Abruptly, he told the two women to lie on banana leaves that had been spread on the floor, so that he could use his visionary powers to search their bodies for tiny points of light, the telltale signature of the sorcerer's darts. As Yankush's intoxication increased, his meditative singing gave way to violent retching. Gaining control of himself, he sucked noisily on the patients' bodies in an effort to remove the darts.

Family members of the patients shouted words of concern and support. "Others know you are curing. They can hurt you, be careful!" one of the spectators warned, referring to the sorcerers whose work the shaman hoped to undo. Torn by anxiety, Chapaik's husband addressed those present: "Who has done this bewitching? If my wife dies, I could kill any man out of anger!" In their cries of encouragement to Yankush, the participants expressed their high regard for the difficult work of the shaman, who at this point in the proceedings was frequently doubled over with nausea caused by the drug he had taken.

Suddenly there was a marked change of atmosphere. A woman named Chimi called out excitedly, "If there are any darts there when she gets back home, they may say that Yankush put them there. So take them all out!" Chimi's statement was an unusually blunt rendering of an ambivalence implicit in all relations between Aguaruna shamans and their clients. Because shamans control spirit darts, people fear that a shaman may be tempted to use the cover of healing as an opportunity to bewitch his own clients for personal reasons. The clients therefore remind the shaman that they expect results—and if such results are not forthcoming, the shaman himself may be suspected of, and punished for, sorcery.

Yankush is such a skilled healer that this threat scarcely caused him to miss a step. He sucked noisily on Yamanuanch's neck to cure her sore throat and, after singing about the sorcery darts lodged in her body, announced she would recover. For good measure, he recommended injections of a commercial antibiotic. Yankush also took pains to emphasize the intensity of his intoxication. Willingness to endure the rigors of a large dose of *ayahuasca* is a sign of his good faith as a healer. "Don't say I wasn't intoxicated enough," he reminded the participants.

As Yankush intensified his singing and rhythmic fanning of the leaf-bundle, he began to have visions of events taking place in distant villages. Suddenly he cried out, "In Achu they killed a person. A sorcerer was killed." "Who could it be?" the other participants asked one another, but before they could reflect on this too long, Yankush had moved on to other matters. "I'm concentrating to throw out sickness, like a tireless jaguar," he sang, referring to Chapaik, who complained of abdominal pains. "With my help she will become like the tapir, which doesn't know how to refuse any kind of food."

After two hours of arduous work, Yankush steered the healing session to its conclusion by reassuring the patients that they were well on their way to recovery. "In her body the sickness will end," he sang. "It's all right. She won't die. It's nothing," he added, returning to a normal speaking voice. Before departing, the patients and their kin discussed the particulars of Yankush's dietary recommendations and made plans for a final healing session to take place at a later date. As the sleepy participants left Yankush's house for their beds in other parts of the village, they expressed their contentment with the results of his efforts.

During the year I lived near Yankush, he conducted healing sessions like this one about twice a month. Eventually, I realized that his active practice was only partly a matter of choice. To allay suspicions and demonstrate his good faith as a healer, he felt compelled to take some cases he might otherwise have declined. Even so, when I traveled to other villages, people sometimes asked me how I could live in a community where a "sorcerer" practiced on a regular basis.

When a respected elder died suddenly of unknown causes in 1976, Yankush came under extraordinary pressure to identify the sorcerer responsible. From the images of his *ayahuasca* vision he drew the name of a young man from a distant region who happened to be visiting a nearby village. The man was put to death in a matter of days. Because Yankush was widely known to have fingered the sorcerer, he became the likely victim of a reprisal raid by members of the murdered man's family. Yankush's willingness to accept this risk in order to protect his community from future acts of sorcery was a source of his social prestige, but it was also a burden. I rarely saw him leave his house without a loaded shotgun.

In calling attention to the violent undercurrents of shamanism, my intention is not to disparage the healing traditions of the Aguaruna or of any other tribal people. I have no doubt that the cathartic drama I witnessed in Yankush's house made the two patients feel better. Medical anthropologists agree that rituals calling forth expressions of community support and concern for sick people often lead to a marked improvement in their sense of well-being. Shamans also serve their communities by administering herbal medications and other remedies and even, as in Yankush's case, helping to integrate traditional healing arts with the use of modern pharmaceuticals. At the same time, however, they help sustain a belief in sorcery that exacts a high price in anxiety and, from time to time, in human life.

In their attempts to understand this negative current, anthropologists have studied how shamanism and accusations of sorcery define local patterns of power and control. Belief in sorcery, for example, may provide a system of rules and punishments in societies that lack a police force, written laws, and a formal judicial system. It helps people assign a cause to their misfortunes. And it sustains religions that link human beings with the spirit world and with the tropical forest itself.

What I find unsettling, rather, is that New Age America seeks to embrace shamanism without any appreciation of its context. For my Santa Fe acquaintances tribal lore is a supermarket from which they choose some tidbits while spurning others. They program computers or pursue other careers by day so that by night they can wrestle with spirit-jaguars and search for their power spots. Yankush's lifetime of discipline is reduced to a set of techniques for personal development stripped of links to a specific landscape and cultural tradition.

New Age enthusiasts are right to admire the shamanistic tradition, but while advancing it as an alternative to our own healing practices, they brush aside its stark truths. For throughout the world shamans see themselves as warriors in a struggle against the shadows of the human heart. Shamanism affirms life but also spawns violence and death. The beauty of shamanism is matched by its power—and like all forms of power found in society, it inspires its share of discontent.

Michael Fobes Brown, an associate professor of anthropology at Williams College, Williamstown, Massachusetts, has spent the past year as a resident scholar at the School of American Research in Santa Fe. His most recent book is Tsewa's Gift: Magic and Meaning in an Amazonian Society.

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The Creation Myths of Cooperstown

Or why the Cardiff Giants are an unbeatable and appropriately named team

by Stephen Jay Gould

You may either look upon the bright side and say that hope springs eternal or, taking the cynic's part, you may mark P. T. Barnum as an astute psychologist for his proclamation that suckers are born every minute. The end result is the same: you can, Honest Abe notwithstanding, fool most of the people all of the time. How else to explain the long and continuing compendium of hoaxes—from the medieval shroud of Turin to Edwardian Piltdown Man to an ultramodern array of flying saucers and astral powers—eagerly embraced for their consonance with our hopes or their resonance with our fears

Some hoaxes make a sufficient mar upon history that their products acquir the very status initially claimed by fak ery—legitimacy (although as an object o human or folkloric, rather than natural history. I once held the bones of Piltdow Man and felt that I was handling an im portant item of Western culture).

The Cardiff Giant, the best America entry for the title of paleontological hoa turned into cultural history, now lies o display in a shed behind a barn at th Farmer's Museum in Cooperstown, Ne York. This gypsum man, more than te feet tall, was "discovered" by workme digging a well on a farm near Cardiff New York, in October 1869. Eagerly em braced by a gullible public, and ardentl displayed by its creators at fifty cents pop, the Cardiff Giant caused quite brouhaha around Syracuse, and then na tionally, for the few months of its activ life between exhumation and exposure.

The Cardiff Giant was the brainchild o George Hull, a cigar manufacturer (an general rogue) from Binghamton, Ne York. He quarried a large block of gyp sum from Fort Dodge, Iowa, and shippe it to Chicago, where two marble cutter fashioned the rough likeness of a nake man. Hull made some crude and minima attempts to give his statue an aged appear ance. He chipped off the carved hair an beard because experts told him that suc items would not petrify. He drove darnin needles into a wooden block and ham mered the statue, hoping to simulate ski pores. Finally, he dumped a gallon of sul furic acid all over his creation to simulat extended erosion. Hull then shipped hi giant in a large box back to Cardiff.

Hull, as an accomplished rogue, sense that his story could not hold for long and in that venerable and alliterative motto got out while the getting was good. He

New York State Historical Association

The Cardiff Giant on display at the Farmer's Museum, Cooperstown, New York

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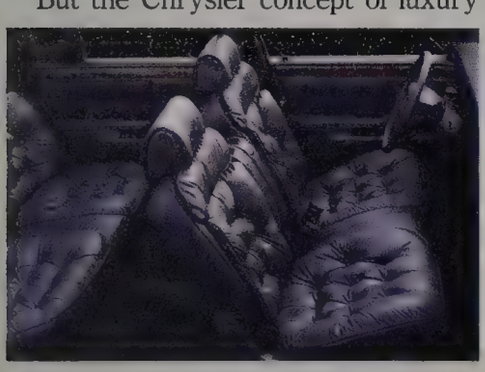

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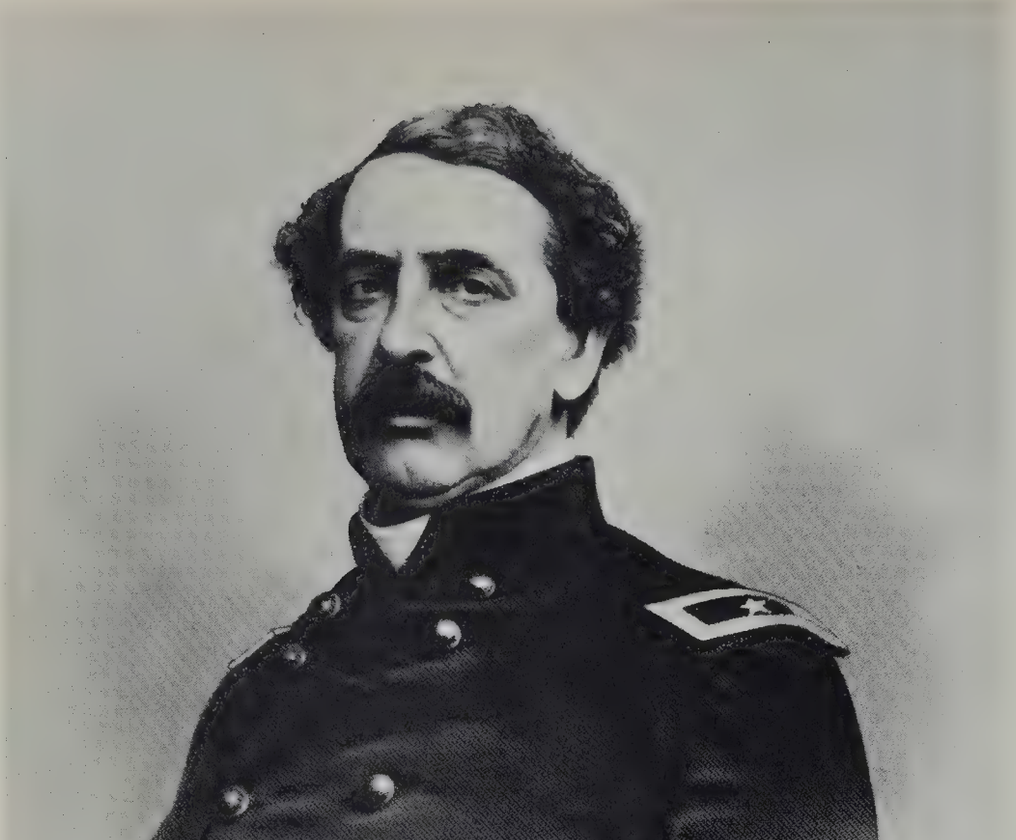

Abner Doubleday

National Baseball Hall of Fame and Museum

official tale proclaims; in fact, no one invented baseball at any moment or in any spot. Nonetheless, this creation myth made Cooperstown the official home of baseball, and the Hall of Fame, with its associated museum and library, set its roots in this small village, inconveniently located near nothing in the way of airports or accommodations. We all revel in bucolic imagery on the field of dreams, but what a hassle when tens of thousands line the roads, restaurants, and port-a-potties during the annual Hall of Fame weekend, when new members are enshrined and two major league teams arrive to play an exhibition game at Abner Doubleday Field, a sweet little 10,000-seater in the middle of town. Put your compass point at Cooperstown, make your radius at Albany—and you'd better reserve a year in advance if you want any accommodation within the enormous resulting circle.

After a lifetime of curiosity, I finally got the opportunity to witness this annual version of forty students in a telephone booth or twenty circus clowns in a Volkswagen. Since Yaz (former Boston star Carl Yastrzemski to the uninitiated) was slated to receive baseball's Nobel in 1989, and his old team was playing in the Hall of Fame game, and since I'm a transplanted Bostonian (although still a New Yorker and not-so-secret Yankee fan at heart), Tom Heitz, chief of the wonderful baseball library at the Hall of Fame, kindly invited me to join the sardines in this most lovely of all cans.

The silliest and most tendentious of baseball writing tries to wrest profundity from the spectacle of grown men hitting a ball with a stick by suggesting linkages between the sport and deep issues of morality, parenthood, history, lost innocence, gentleness, and so on, seemingly *ad infinitum*. (The effort reeks of silliness because baseball is profound all by itself and needs no excuses; people who don't know this are not fans and are therefore unreachable anyway.) When people ask me how baseball imitates life, I can only respond with what the more genteel newspapers used to call a "barnyard epithet," but now, with growing bravery, usually rende as "bullbleep." Nonetheless, baseball is major item of our culture, and it does hav a long and interesting history. Any item c institution with these two properties mus generate a set of myths and stories (pe haps even some truths) about its begi nings. And the subject of beginnings is th bread and butter of this column on evolu tion in the broadest sense. I shall make n woolly analogies between baseball an life; this is an essay on the origins of base ball, with some musings on why begi nings of all sorts hold such fascination fo us. (I thank Tom Heitz not only for th invitation to Cooperstown at its yearl acme but also for drawing the contra between creation and evolution stories c baseball, and for supplying much usefu information from his unparalleled stor house.)

Stories about beginnings come in on two basic modes. An entity either has a explicit point of origin, a specific time an place of creation, or else it evolves and ha no definable moment of entry into th world. Baseball provides an interesting e ample of this contrast because we kno the answer and can judge received wi dom by the two chief criteria, often o posed, of external fact and internal hop Baseball evolved from a plethora of prev ous stick-and-ball games. It has no tru Cooperstown and no Doubleday. Yet w seem to prefer the alternative model origin by a moment of creation—for the we can have heroes and sacred places. B contrasting the myth of Cooperstown wi the fact of evolution, we can learn som thing about our cultural practices an their frequent disrespect for truth.

The official story about the beginni of baseball is a creation myth, and a r view of the reasons and circumstances its fabrication may give us insight into th cultural appeal of stories in this mod A. G. Spalding, baseball's first gre pitcher during his early career, lat founded the sporting goods company th still bears his name and became one of th great commercial moguls of America gilded age. As publisher of the annu *Spalding's Official Base Ball Guide,* held maximal power in shaping both pu lic and institutional opinion on all facets baseball and its history. As the sport gre in popularity, and the pattern of two stab major leagues coalesced early in our ce tury, Spalding and others felt the need f clarification (or merely for codificatio of opinion on the hitherto unrecorded o gins of an activity that truly merited common designation as America's "n tional pastime."

In 1907, Spalding set up a blue ribb

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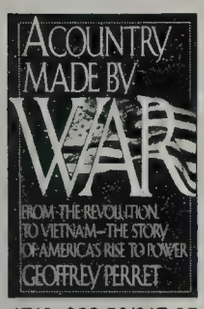

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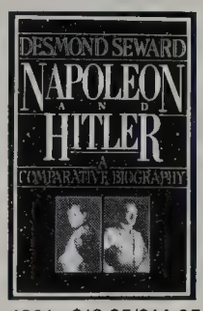

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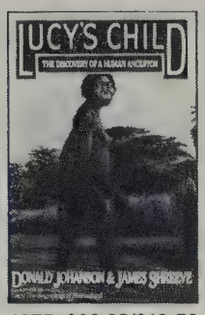

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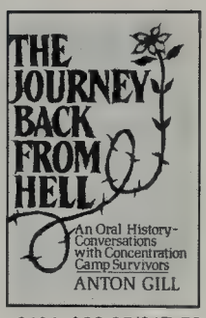

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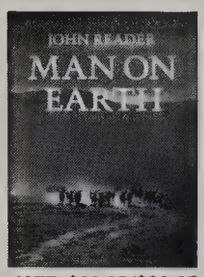

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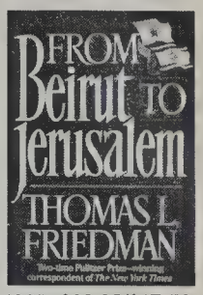

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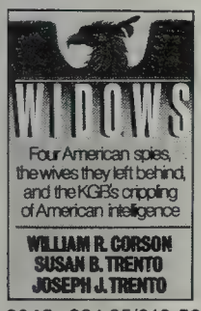
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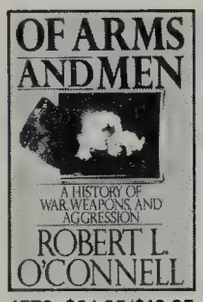

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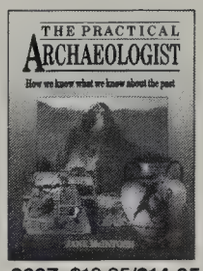

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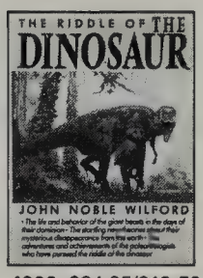

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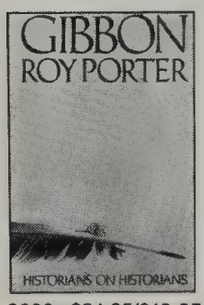

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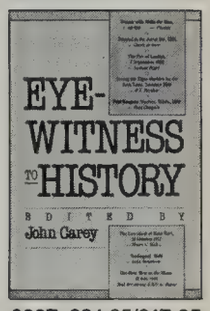

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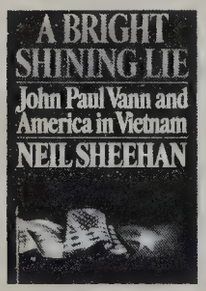

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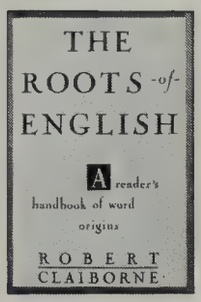

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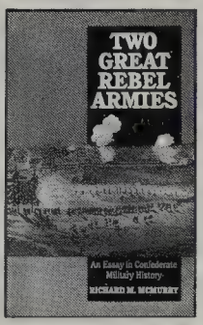

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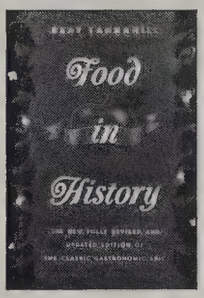

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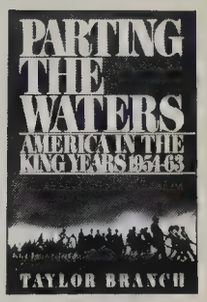

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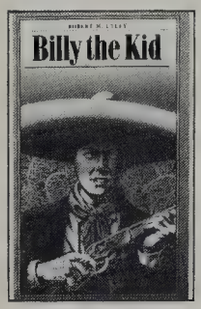

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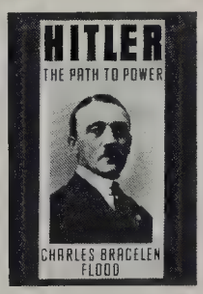

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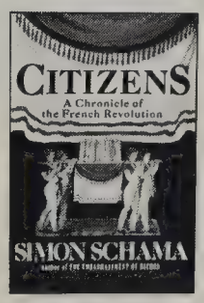

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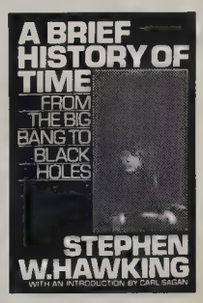

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committee to investigate and resolve the origins of baseball. The committee, chaired by A. G. Mills and including several prominent businessmen and two senators who had also served as presidents of the National League, took much testimony but found no smoking gun for a beginning. Then, in July 1907, Spalding himself transmitted to the committee a letter from an Abner Graves, then a mining engineer in Denver, who reported that Abner Doubleday had, in 1839, interrupted a marbles game behind the tailor's shop in Cooperstown, New York, to draw a diagram of a baseball field, explain the rules of the game, and designate the activity by its modern name of "base ball" (then spelled as two words).

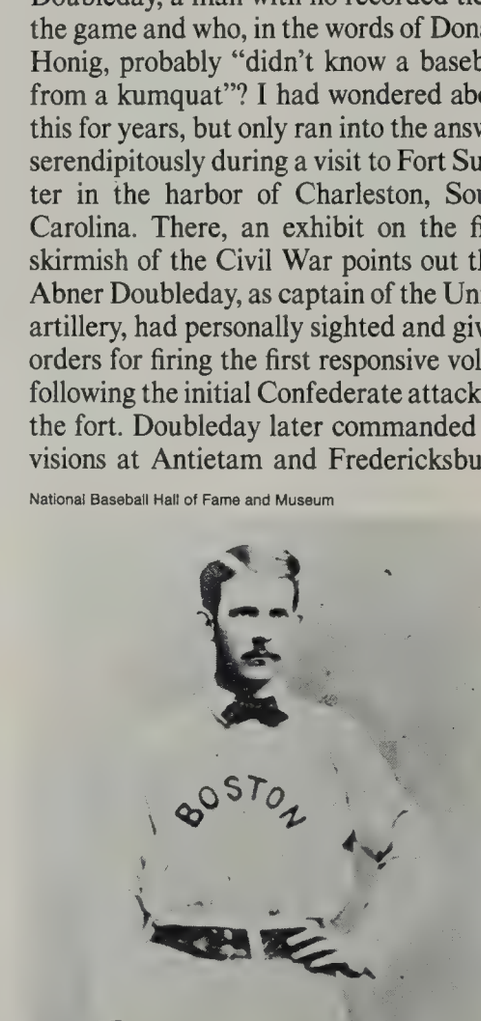
Such "evidence" scarcely inspired universal confidence, but the commission came up with nothing better—and the Doubleday myth, as we shall soon see, was eminently functional. Therefore, in 1908, the Mills Commission reported its two chief findings: first, "that base ball had its origins in the United States"; and second, "that the first scheme for playing it, according to the best evidence available to date, was devised by Abner Doubleday, at Cooperstown, New York, in 1839." This "best evidence" consisted only of "a circumstantial statement by a reputable gentleman"—namely Graves's testimony as reported by Spalding himself.

When cited evidence is so laughably insufficient, one must seek motivations other than concern for truth value. The key to underlying reasons stands in the first conclusion of Mills's committee: hoopla and patriotism (cardboard version) decreed that a national pastime must have an indigenous origin. The idea that baseball had evolved from a wide variety of English stick-and-ball games—although true—did not suit the mythology of a phenomenon that had become so quintessentially American. In fact, Spalding had long been arguing, in an amiable fashion, with Henry Chadwick, another pioneer and entrepreneur of baseball's early years. Chadwick, born in England, had insisted for years that baseball had developed from the British stick-and-ball game called rounders; Spalding had vociferously advocated a purely American origin, citing the colonial game of "one old cat" as a distant precursor, but holding that baseball itself represented something so new and advanced that a pinpoint of origin—a creation myth—must be sought.

Chadwick considered the matter of no particular importance, arguing (with eminent justice) that an English origin did not "detract one iota from the merit of its now being unquestionably a thoroughly American field sport, and a game too, which is fully adapted to the American character." (I must say that I have grown quite fond of Mr. Chadwick, who certainly understood evolutionary change and its chief principle that historical origin need not match contemporary function.) Chadwick also viewed the committee's whitewash as a victory for his side. He labeled the Mills report as "a masterful piece of special pleading which lets my dear old friend Albert [Spalding] escape a bad defeat. The whole matter was a joke between Albert and myself."

We may accept the psychic need for an indigenous creation myth, but why Abner Doubleday, a man with no recorded tie to the game and who, in the words of Donald Honig, probably "didn't know a baseball from a kumquat"? I had wondered about this for years, but only ran into the answer serendipitously during a visit to Fort Sumter in the harbor of Charleston, South Carolina. There, an exhibit on the first skirmish of the Civil War points out that Abner Doubleday, as captain of the Union artillery, had personally sighted and given orders for firing the first responsive volley following the initial Confederate attack on the fort. Doubleday later commanded divisions at Antietam and Fredericksburg, became at least a minor hero at Gettysburg, and retired as a brevet major general. In fact, A. G. Mills, head of the commission, had served as part of an honor guard when Doubleday's body lay in state in New York City, following his death in 1893.

National Baseball Hall of Fame and Museum



A. G. Spalding

If you have to have an American hero could anyone be better than the man who fired the first shot (in defense) of the Civil War? Needless to say, this point was not lost on the members of Mills's committee. Spalding, never one to mince words, wrote to the committee when submitting Graves's dubious testimony: "It certainly appeals to an American pride to have had the great national game of base ball created and named by a Major General in the United States Army." Mills then concluded in his report: "Perhaps in the years to come, in view of the hundreds of thousands of people who are devoted to baseball, and the millions who will be, Abner Doubleday's fame will rest evenly, if not quite as much, upon the fact that he was its inventor . . . as upon his brilliant and distinguished career as an officer in the Federal Army."

And so, spurred by a patently false creation myth, the Hall of Fame stands in the most incongruous and inappropriate locale of a charming little town in central New York. Incongruous and inappropriate, but somehow wonderful. Who needs another museum in the cultural maelstroms (and summer doldrums) of New York, Boston, or Washington? Why not a major museum in a beautiful and bucolic setting? And what could be more fitting than the spatial conjunction of two great American origin myths—the Cardiff Giant and the Doubleday Fable? Thus, I too am quite content to treat the myth gently, while honesty requires 'fessing up. The exhibit on Doubleday in the Hall of Fame Museum sets just the right tone in its caption: "In the hearts of those who love baseball, he is remembered as the lad in the pasture where the game was invented. Only cynics would need to know more." Only in the hearts; not in the minds.

Baseball evolved. Since the evidence is so clear (as epitomized below), we must ask why these facts have been so little appreciated for so long, and why a creation myth like the Doubleday story ever gained a foothold. Two major reasons have conspired: first, the positive block of our attraction to creation stories; second, the negative impediment of unfamiliar sources outside the usual purview of historians. English stick-and-ball games of the nineteenth century can be roughly classified into two categories along social lines. The upper and educated classes

Tomorrow, another species will vanish from the earth.

SHOWN ACTUAL SIZE.

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played cricket, and the history of this sport is copiously documented because the literati write about their own interests, and because the activities of men in power are well recorded (and constitute virtually all of history, in the schoolboy version). But the ordinary pastimes of rural and urban working people can be well nigh invisible in conventional sources of explicit commentary. Working people played a different kind of stick-and-ball game, existing in various forms and designated by many names, including "rounders" in western England, "feeder" in London, and "base ball" in southern England. For a large number of reasons, forming the essential difference between cricket and baseball, cricket matches can last up to several days (a batsman, for example, need not run after he hits the ball and need not expose himself to the possibility of being put out every time he makes contact). The leisure time of working people does not come in such generous gobs, and the lower-class stick-and-ball games could not run more than a few hours.

Several years ago, at the Victoria and Albert Museum in London, I learned an important lesson from an excellent exhibit on the late nineteenth century history of the British music hall. This is my favorite period (Darwin's century, after all), and I consider myself tolerably well informed on cultural trends of the time. I can sing any line from any of the Gilbert and Sullivan operas (a largely middle-class entertainment), and I know the general drift of high cultural interests in literature and music. But here was a whole world of entertainment for millions, a world with its heroes, its stars, its top forty songs, its gaudy theaters—and I knew nothing, absolutely nothing, about it. I felt chagrined, but my ignorance had an explanation beyond personal insensitivity (and the exhibit had been mounted explicitly to counteract the selective invisibility of certain important trends in history). The music hall was the chief entertainment of Victorian working classes, and the history of working people is often invisible in conventional written sources. It must be rescued and reconstituted from different sorts of data; in this case, from posters, playbills, theater accounts, persistence of some songs in the oral tradition (most were never published as sheet music), recolle tions of old-timers who knew the perso who knew the person . . . .

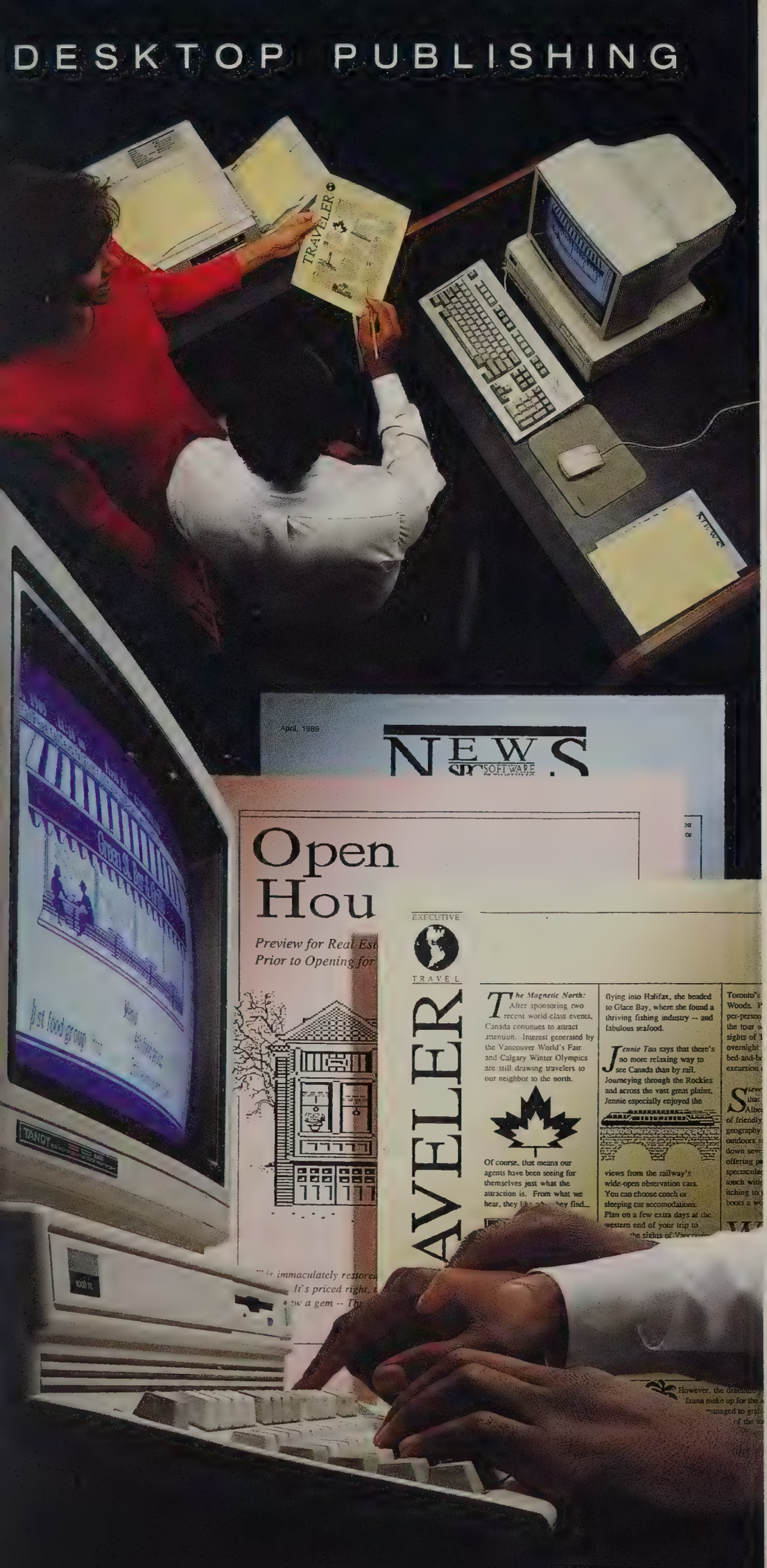
The early history of baseball—th stick-and-ball game of working people– presents the same problem of conve tional invisibility—and the same promis of rescue by exploration of unusu sources. Work continues and intensifies the history of sport becomes more an more academically respectable, but th broad outlines (and much fascinatin detail) are now well established. As th upper classes played a codified an well-documented cricket, working peop played a largely unrecorded and muc more diversified set of stick-and-ba games ancestral to baseball. Man sources, including primers and boys' man uals, depict games recognizable as precu sors to baseball well into the early eigh eenth century. Occasional references eve spill over into high culture. In *Northange Abbey,* written at the close of the eigh eenth century, Jane Austen remarks: "I was not very wonderful that Catherin . . . should prefer cricket, base ball, ridin on horseback, and running about the coun try, at the age of fourteen, to books." A this quotation illustrates, the name of th game is no more Doubleday's than th form of play.

These ancestral styles of baseball cam to America with early settlers and wer clearly well established by colonial time But they were driven ever further unde ground by Puritan proscriptions of spo for adults. They survived largely as chi dren's games and suffered the doubl invisibility of location among the poor an the young. But two major reasons brough these games into wider repute and led to codification of standard forms quite clos to modern baseball between the 1820s an the 1850s. First, a set of social reasons from the decline of Puritanism to in creased concern about health and hygien in crowded cities, made sport an accep able activity for adults. Second, middle class and professional people began t take up these early forms of baseball, an with this upward social drift came teams leagues, written rules, uniforms, stadiums guidebooks: in short, all the paraphernali of conventional history.

I am not arguing that these early game could be called baseball with a few trivia differences (evolution means substantia change, after all), but only that they stan in a complex lineage, better called nexus, from which modern baseba emerged, eventually in a codified and ca nonical form. In those days before instan communication, every region had its ow version, just as every set of outdoor step

Henry Chadwick

National Baseball Hall of Fame and Museum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in New York City generated a different form of stoopball in my youth, without threatening the basic identity of the game. These games, most commonly called town ball, differed from modern baseball in substantial ways. In the Massachusetts Game, a codification of the late 1850s drawn up by ballplayers in New England towns, four bases and three strikes identify the genus, but many specifics are strange by modern standards. The bases were made of wooden stakes projecting four feet from the ground. The batter (called the striker) stood between first and fourth base. Sides changed after a single out. One hundred runs (called tallies), not higher score after a specified number of innings, spelled victory. The field contained no foul lines, and balls hit in any direction were in play. Most importantly, runners were not tagged out but were retired by "plugging," that is, being hit with a thrown ball while running between bases. Consequently, since baseball has never been a game for masochists, balls were soft—little more than rags stuffed into leather covers—and could not be hit far. (Tom Heitz has put together a team of Cooperstown worthies to re-create town ball for interested parties and prospective opponents. Since few other groups are well schooled in this lost art, Tom's team hasn't been defeated in ages, if ever. "We are the New York Yankees of town ball," he told me. His team is called, quite appropriately in general but especially for this essay, the Cardiff Giants.)

Evolution is continual change, but not insensibly gradual transition; in any continuum, some points are always more interesting than others. The conventional nomination for most salient point in this particular continuum goes to Alexander Joy Cartwright, leader of a New York team that started to play in Lower Manhattan, eventually rented some changing rooms and a field in Hoboken (just a quick ferry ride across the Hudson), and finally drew up a set of rules in 1845, later known as the New York Game. Cartwright's version of town ball is much closer to modern baseball, and many clubs followed his rules—for standardization became ever more vital as the popularity of early baseball grew and opportunity for play between regions increased. In particular, Cartwright introduced two key innovations that shaped the disparate forms of town ball into a semblance of modern baseball. First, he eliminated plugging and introduced tagging in the modern sense; the ball could now be made harder, and hitting for distance became an option. Second, he introduced foul lines, again in the modern sense as his batter stood at a

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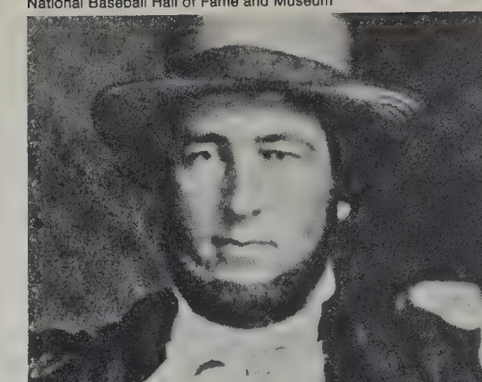

Alexander Joy Cartwright

home plate and had to hit the ball within lines defined from home through first and third bases. The game could now become a spectator sport because areas close to the field but out of action could, for the first time, be set aside for onlookers.

The New York Game may be the highlight of a continuum, but it provides no origin myth for baseball. Cartwright's rules were followed in various forms of town ball. His New York Game still included many curiosities by modern standards (twenty-one runs, called aces, won the game, and balls caught on one bounce were outs). Moreover, our modern version is an amalgam of the New York Game plus other town ball traditions, not Cartwright's baby grown up by itself. Several features of the Massachusetts Game entered the modern version in preference to Cartwright's rules. Balls had to be caught on the fly in Boston, and pitchers threw overhand, not underhand as in the New York Game (and in professional baseball until the 1880s).

Scientists often lament that so few people understand Darwin and the principles of biological evolution. But the problem goes deeper. Too few people are comfortable with evolutionary modes of explanation in any form. I do not know why we tend to think so fuzzily in this area, but one reason must reside in our social and psychic attraction to creation myths in preference to evolutionary stories—for creation myths, as noted before, identify heroes and sacred places, while evolutionary stories provide no palpable, particular thing as a symbol for reverence, worship, or patriotism. Still, we must remember—and an intellectual's most persistent and nagging responsibility lies in making this simple point over and over again, however noxious and bothersome we render ourselves thereby—that truth and desire, fact and comfort, have no necessary, or eve preferred, correlation (so rejoice whe they do coincide).

To state the most obvious example i our current political turmoil. Huma growth is a continuum, and no creatio myth can define an instant for the origin o an individual life. Attempts by antiabo tionists to designate the moment of ferti ization as the beginning of personhoo make no sense in scientific terms (and als violate a long history of social definitior that traditionally focused on the quicken ing, or detected movement, of the fetus i the womb). I will admit—indeed, I em phasized as a key argument of this e say—that not all points on a continuu are equal. Fertilization is a more interes ing moment than most, but it no mor provides a clean definition of origin tha the most interesting moment of baseball continuum—Cartwright's codification o the New York Game—defines the begi ning of our national pastime. Baseba evolved and people grow; both are co tinua without definable points of origi Probe too far back and you reach absu dity, for you will see Nolan Ryan on th hill when the first ape hit a bird with stone; or you will define both masturba tion and menstruation as murder—an who will then cast the first stone? Look fo something in the middle, and you fin nothing but continuity—always a mean ingful "before," and always a more mod ern "after." (Please note that I am no stating an opinion on the vexatious que tion of abortion—an ethical issue that ca only be decided in ethical terms. I onl point out that one side has rooted its cas in an argument from science that is no only entirely irrelevant to the proper realm of resolution but also happens to be fla out false in trying to devise a creatio myth within a continuum.)

And besides, why do we prefer creatio myths to evolutionary stories? I find all th usual reasons hollow. Yes, heroes an shrines are all very well, but is there no grandeur in the sweep of continuity? Sha we revel in a story for all humanity tha may include the sacred ball courts of th Aztecs, and perhaps, for all we know, group of *Homo erectus* hitting rocks o skulls with a stick or a femur? Or shall w halt beside the mythical Abner Double day, standing behind the tailor's shop i Cooperstown, and say "behold th man"—thereby violating truth and, per haps even worse, extinguishing bot thought and wonder?

Stephen Jay Gould teaches biology, geo ogy, and the history of science at Harvar University.

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Bittersweet Dreams of Glor

What motivated Robert Peary to claim that he had reached the North Po

by Jared Diamond

"For more than a score of years, that point on the earth's surface had been the object of my every effort . . . . This was my final chance to realize the one dream of my life. . . . Mine at last!"

—ROBERT PEARY,
of his last attempt, at age fifty-two, to reach the North Pole.

"If it had not been for this thing, I might have lived out my life talking at street corners to scorning men. I might have died unmarked, unknown, a failure. Now we are not a failure."

—BARTOLOMEO VANZETTI,
from a letter to his son, written four months before his death.

On April 6, 1909, during the last of his eight arctic expeditions, explorer Robert Peary was confronted with a cruel di lemma. Six days previously he hac reached latitude 87°47′ north, already new record. From there he had headed, h thought, in the direction of his life's on dream, the place that would save him from dying a failure: the North Pole. I growing excitement he had fantasized about the wealth and fame that would become his for this achievement. But h hadn't measured his longitude to confirm his position.

Now, on April 6, he finally determined his latitude again. As best we can recon struct it today, he found that he was still a least fifty miles short of the pole. Wha was he to do? Should he confess his navi gational error to his companions, keep go

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Peary

Telegram sent by Peary

ing to the pole, and risk dying of starvation on his return, as would antarctic explorer Robert Scott? Should he turn back now without reaching the pole, acknowledge his error, and spend the rest of his life talking to scorning men? Or should he put the best face on the situation and return to claim at least a new "farthest north" record, for which he had already been acclaimed as a hero in 1906?

It was more than two months before Peary fully resolved his dilemma. Two recent, fine books help us guess what may have been going on in his mind then: Wally Herbert's *The Noose of Laurels* and Pierre Berton's *The Arctic Grail*. To give himself freedom of action, on April 6 Peary did not ask his companion Matthew Henson to check his navigational readings, and he scarcely spoke to Henson during the whole return journey. He left his diary pages blank for April 7 and 8, while for April 6 itself there remains only a loose-leaf page that he may have inserted later. On rejoining his other companions at his ship on April 27, he volunteered no specifics about how far he had gotten, and he evaded all questions. Not until June 12 did he state his claim that he had reached the pole.

That claim has always been controversial. Peary reported that he had headed in a straight line for the pole, but how could he know that when he had never measured his longitude? He also reported that he hadn't detoured for obstacles and hadn't been carried east or west by ice drift on the Arctic Ocean. Yet all other explorers at those latitudes have experienced detours and drift, and Peary himself had described them earlier. His claimed speeds suddenly increased as soon as his last companion who could perform navigational calculations turned back. Making allowances for detours and drift, those claimed speeds are greater than anyone (including Peary) has achieved under similar conditions. He could not have known his exact

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position because his watch was ten minutes in error, and he apparently ignored magnetic variation of the compass. Now that his original diary has been recently examined by Wally Herbert and found to be blank or loose-leaf for those three crucial days nearest the pole, his claim has become harder than ever to believe.

Why did Peary falsely claim to have reached the pole—*if* his claim was false? It's easy now to dismiss him as one more perpetrator of fraud, and to dismiss his quandary as too exotic to hold meaning for our everyday lives. But life isn't so black and white, and people aren't either pure heroes or pure villains. In particular, Peary's options on April 6 weren't as simple as they might at first seem. Far from being a fraud, he was the most successful arctic explorer ever, whether he actually reached the pole or a spot fifty miles from it. And his dilemma was neither exotic nor peculiar to him, but instead a universal human one.

All of us, like Peary, eventually have to make peace with our failed dreams. When we're in our twenties, life still feels infinitely long, and we tacitly assume that there's enough time for any of our fantasies still to happen to us. They feel like realistic hopes. But eventually, perhaps in our forties, we realize that time isn't infinite and that some of our dreams will always remain no more than that. Whatever we have achieved, there will be some things that we badly wanted to achieve and didn't: for the most ambitious of us, perhaps a Nobel Prize or fame; for all of us, things that we sought in marriage, friendships, or other sources of satisfaction. We then have to make peace not only with the ways in which life betrayed us but also with the ways in which we betrayed ourselves and those closest to us. By our fifties, most of us hear the clock's ticking, and the problem of making peace with failed dreams becomes acute.

That was the familiar dilemma that confronted Peary. It was more acute for him than for many of us, because his efforts were so focused on a single goal with a yes/no answer, and because his quest to avoid failure was played out in public view. Thus, Peary's story is a homely one writ large.

I already said that Peary was the most successful arctic explorer ever. His achievements included the crossing of northwest Greenland, the proof that Greenland is an island, but especially his getting farther north and back without motorized assistance than anyone else has before or since. Those achievements weren't an accident but resulted directly from his abilities. At a time when European exploration of the Arctic had been a catalog of disasters led by amateurs, who scorned Eskimo experience and burdened themselves with large parties and several ships, Peary revolutionized arctic exploration by combining the best of Eskimo and European inventiveness. No amateur, he took risks seriously and planned in great detail. He used small parties and a revolutionary icebreaker ship that he conceived. He redesigned stoves for cold conditions and designed sledges almost ten times lighter than the ones that had crushed the Franklin expedition. Most of his companions were the people with the most arctic experience: Eskimo. Almost alone among modern explorers, his field parties included (Eskimo) women, who sewed specialized arctic clothing and (in Peary's words) served "to render the men contented." From Eskimo he learned reliance on dogs, rather than men, to pull sledges; construction of igloos rather than carrying tents; sleeping in clothes rather than in sleeping bags; and living off fresh hunted meat rather than scurvy-promoting tinned meat.

For actual field travel Peary devised a meticulously organized system of trail-blazing teams, teams to carry supplies, and a team to make the final push. The latter team was thereby enabled to make the push rested and well supplied and to return quickly. The quantities of supplies and the timing of parties were worked out down to such details as which dogs would eat which other dogs at which point. Methods based on this "Peary system," as he termed it, are now standard in exploration and mountaineering.

Today, it is unlikely that anyone will ever come close to matching Peary's record for a return journey to (or almost to) the North Pole without motors. The trained sledge dogs, the experienced Eskimo, and the financial backing could now no longer be obtained. Everyone who has reached the North Pole since Peary has been flown out by airplane, and everyone but Will Steger in 1986 has been supplied en route by air drops. If anyone was entitled by ability to reach the North Pole, it was Peary, and he knew it.

There was another set of grounds on which Peary felt entitled to the pole: his sacrifices and efforts during eight expeditions that consumed almost all of his time, energy, and money from 1886 to 1909. Of those twenty-three years, he spent half actually in the Arctic and the remainder in the United States raising money and preparing for each next trip. He mortgaged himself to the point of bankruptcy, delivered up to 165 money-raising speeches in 103 days, and incessantly wrote and visited prospective backers. At the start of the 1891–2 expedition he lost eight of his toes to frostbite, endured a 250-mile trip back to his ship in excruciating pain, and still set out again five weeks later. For the rest of his life he struggled to walk on the stumps of his feet, and both they and his broken leg left him in agony on later expeditions.

Peary and his wife, Josephine

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Peary's sacrifices also included his relationships with his wife, mother, and children, from whom he was separated and out of touch with for years at a time. Late in the 1898–1902 expedition he learned that in his absence his mother had died, his wife had given birth to his second daughter, and that that daughter had died. He wrote his wife that he felt their life

> slipping away . . . . I have had but one thought, an intense unevadable longing for you and my babies . . . . A great slice out of our lives, apart from each other.

In 1900 he still looked forward to the day when "I shall accomplish my object and then hand in hand we will meet the days and years until the end comes." But by 1902 he thought of himself as

> a maimed old man, unsuccessful after the most arduous work, away from wife and child, mother dead, one baby dead . . . . When I think of the last four years, and what I have been through, as I think of all the petty details, it all seems so small, so little worth the while that I could cry out in anguish of spirit.

If it had only been his own sacrifices and efforts that were frustrated on April 6, 1909, Peary could perhaps have acknowledged the failure of the dream to whose achievement he felt entitled. But others had also sacrificed to help him reach his goal, and they counted on his success to give meaning to their sacrifices. To begin with, there were his financial backers, the members of the Peary Arctic Club, who had been contributing generously of their money and time for eleven years. To enlist their support, Peary had promised them fame by association.

> If I win out in this work, the names of those who made the work possible will be kept through the coming centuries floating forever above the forgotten and submerged debris of our time and day. The one thing we remember about Ferdinand of Spain is that he sent Columbus to his life work.

There were also Presidents McKinley and Theodore Roosevelt, who had placed themselves at risk for Peary by granting him repeated paid leaves of three to five years from the Navy, over the objections of the Secretary of the Navy. Peary had promised his best: "Mr. President, I shall put into this effort everything there is in me—physical, mental, and moral." And President Roosevelt's response: "I believe in you, Peary, and I believe in your success."

By 1909, the sole success still worth aiming for was the North Pole itself. It wasn't good enough to set yet another new record for reaching the farthest north short of the pole. Peary had already had to deliver his backers that consolation prize once before, in 1906. This time, Roosevelt told him, "The attainment of the pole should be your main objective." The New York Times was even more explicit: the $4,000 contribution that it gave Peary was to be refunded if he failed to reach the pole. Should he acknowledge failure, no one would send him north once again nor would his age permit it.

Those sacrifices were of money and backing, but there were others who made more personal sacrifices, and whom Peary had already betrayed. Were those sacrifices and betrayals to be in vain? For example, there were his Eskimo companions who died in an epidemic in his camp in 1901. There was Bob Bartlett, the ship captain who devoted himself to Peary for three expeditions spanning a decade, under one condition: that he be permitted to join Peary on the dash to the pole itself. Without Bartlett's skill, Peary's ship would never have broken through the i pack to reach the Arctic Ocean in 1905 1908, and would never have survived t return trip in 1906 with a broken propell and rudder, leaking boiler, and exhaust fuel supply. Bartlett personally bro much of the trail over the polar ice March 1909, only to be ordered by Pea on March 31, 150 miles short of the pol to return to base camp the next day.

There was also Peary's mother, who ha lived only for Peary, and who died in 19 in the middle of one of his four-year arct trips. Peary did not learn of her death un he received a letter from his cousin eig months later: "I am sure that for son weeks before she went away, she felt yo were no longer living, and I think a part her life went out at that time."

There was also Peary's wife, Josephin who endured years away from him, n knowing if he was still alive, and who w

On the deck of the SS Roosevelt, *President Roosevelt bids Peary farewell.*

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shocked to meet Peary's Eskimo mistress and child during an unannounced visit to his ship. Josephine had borne and lost her own child by Peary in his absence, as she wrote him after the child's death:

> Our little darling whom you never knew was taken from me on August 7th, 1899, just seven months after she came . . . . Oh, my husband I wanted you, how much you will never know. I shall never feel quite the same again, part of me is in the little grave. . . . Oh, Sweetheart, husband, together we could have shared it but alone it was almost too much.

Finally, there was Peary's surviving daughter, Marie, who wrote him shortly after her ninth birthday,

> I read that the Peary Arctic Club are trying to get your consent to go north again. I think it is a dogs shame and wish every member of the Club were dead then you would not have to go in the first place. I know you will do what pleases Mother and me and that is to stay with us at home. I have been looking at your pictures and it seems ten years and I am sick of looking at them. I want to see my father. I don't want people to think of me as an orphan. Please think this over. Your loving Marie.

Of course, Peary thought it over—and decided to go north again. He surely thought over Marie's letter once again on April 6, 1909, along with that letter from his wife, that letter about his mother's death, his dismissal of Bob Bartlett, his dead Eskimo friends, the expectations of his backers and the president, and the New York Times's refundable advance. What answer was he to make for all those sacrifices and betrayals?

The situation on April 6 would have been difficult for anyone. It was especially so for Robert Peary because of how life had molded him. An only child whose father died before he was three, he was raised by his mother, to whom he was everything in life. She reared him as a girl, dressed him in a bonnet, taught him that he was too delicate to play with other boys, sent him off to boarding school at age eight, and moved with him to college. He lisped and was terrified that his mother's death would leave him alone in the world.

Yet he rose to these handicaps, conquered them, and compensated for them. He became self-reliant and ambitious for fame. As he was planning his first expedition (to Nicaragua), he wrote his mother:

> I wish to acquire a name which shall be an "open sesame" to circles of culture and refinement anywhere, a name which shall make my Mother proud and which shall make me feel that I am peer to anyone I may meet.

These wishes blossomed into grandiose fantasies that he confided to his diary during those days in early April 1909, when he thought he was about to achieve the pole. He sketched a design for his mausoleum and an Order of the North Pole, imagined bestowing mementoes of himself, and drafted letters extolling his achievements and recommending his promotion to the rank of rear admiral.

Flags supposedly left at the North Pole by Peary

To achieve the fame that he craved, Peary became single-minded in his obsession with reaching the pole.

> The determination to reach the Pole had become so much a part of my being that, strange as it may seem, I long ago ceased to think of myself save as an instrument for the attainment of that end.

To use Vanzetti's words, the pole was for Peary that one thing that could save him from living out his life talking at street corners to scorning men. With craving for success came also a fear of failure that in March 1900 paralyzed him when he was actually in a position to set out for the pole.

To achieve his one dream, Peary became skilled at captivating and exploiting any useful people whom he encountered, from Eskimo to presidents. Just as his mother had felt no empathy for him, so he too lacked empathy for others. He became paranoid and possessive toward anyone who he imagined might trespass on what he had decided was his to claim. Other great arctic explorers, such as Nansen and Sverdrup, were viewed as threatening to "forestall" him or to "appropriate his work." He felt solely entitled to the pole as he had been to his mother's attention. Let no one else claim the attention that he had received from his mother, that he had been denied by his father's early death and that he now sought from the whole world!

"Grandiose sense of self-importance . . . preoccupation with fantasies of unlimited success, power, wealth . . . extreme self-centeredness . . . goals pursued with a driven, pleasureless quality . . . fragile self-esteem . . . feelings of entitlement . . . interpersonal exploitiveness . . . lack of empathy . . . rights of others disregarded . . . personal defeats justified by outright lying." These words could be a description of Peary. Instead, they come from the description of a condition termed the narcissistic personality disorder in the *Diagnostic and Statistical Manual of Mental Disorders*, published by the American Psychiatric Association. Since "personality disorder" may sound like a polite term for calling someone crazy, let me make emphatically clear that Peary was the reverse of crazy: he was extraordinarily able, persuasive, happily married despite great stress on his marriage.

My reason for quoting this description is to show how in Peary, as in many overachievers, the roots of his strength were inextricably linked to his unattractiv

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Peary party crosses a ridge near Cape Columbia

qualities. The struggle to overcome the handicaps of his childhood shaped Peary's character. Without his ways of coping that grew from that struggle, Peary would not have aimed, or succeeded, at becoming a great explorer—and would not have paid such a heavy price for his greatness.

From his character stemmed also his method of dealing with incomplete success. This method received its most severe test on April 6, 1909, but he had developed it on his earlier expeditions. Between 1891 and 1906 he claimed to discover, and to name for himself and his backers, some apparently impressive geographical features that proved subsequently to be mirages. The closest parallel to Peary's behavior near the North Pole in 1909 was his claimed attainment of a record farthest north on April 21, 1906. Then, too, he had needed an achievement to justify himself and his backers. Then, too, he had dismissed his last companion capable of navigational calculations before the final push, claimed speeds triple his previous speeds after that companion's return, omitted measurements of longitude and compass variation, and claimed travel in a straight line without detours or drift. Then, too, his diary does not contain the latitude measurement he later published in his book.

In retrospect, Peary's solution to the dilemma of April 21, 1906, served as a dry run for the dilemma of April 6, 1909. He had trained to achieve success, and also to cover incomplete success. It merely took some time in April, May, and June of 1909 for him to work out the details of the solution, and to ponder whether it would be credible.

We all eventually face Peary's dilemma—dealing with the failure of a dream. It's hard to acknowledge our failure. It's even harder, having acknowledged it, not to become bitter. All of us know examples, from our own experience and that of friends. All of us also know people who reflect on their failed dreams, as well as on their sources of happiness, are content with the combination, and still say of themselves, "Now we are not a failure."

For Peary, the form in which life posed this universal problem of aging was cruelly difficult. He was burdened by the severe handicaps of his childhood, the price he had to pay to conquer those handicaps, the grandness and single-mindedness of his dream, the dependence of his dream's fulfillment on other people, and the public exposure of his struggle. The solution he found to his dilemma proved bittersweet. Yes, he received twenty-two gold medals, dined with kings, was promoted to rear admiral, and restored his finances through lecture and writing fees. But his triumph was marred by the dispute about Dr. Frederick Cook's much more fraudulent rival claim to have reached the pole. Peary was grilled by a congressional committee over his proposed promotion, and in 1916 a congressional bill was introduced (and failed) to repeal his promotion. In his wife's words,

> The personal grilling which he was obliged to undergo at the hands of Congress . . . hurt him more than all the hardships he endured in his sixteen years of research in the arctic regions and did more towards the breaking down of his iron constitution than anything experienced in his explorations.

Peary was deprived of the days and years, hand in hand with his wife, to which he had looked forward after accomplishing his object. Instead, he died slowly of pernicious anemia, and perhaps of the unshareable burden of knowing that he had just missed achieving the one dream of his life. The epitaph that Winston Churchill wrote for a World War II military leader could also apply to Peary: "Let him rest in peace, and let us all be thankful we have never had to face [his] trials . . . Those who have endured a similar ordeal may judge him."

Jared Diamond teaches physiology at UCLA Medical School and explores the mountains of New Guinea.

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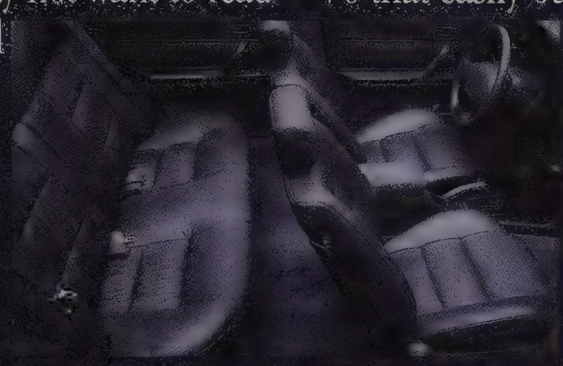

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Did you know that the empty plastic soft drink bottles you throw away every day can be transformed into carpet yarn or automotive parts or fiberfill for ski parkas?

That used glass bottles and aluminum cans can be transformed into new ones?

And that yesterday's newspaper can be transformed into tomorrow's?

It all happens because of recycling. The simple trash we throw away is a "natural resource" that, with recycling, can be used to produce a multitude of new products.

Unfortunately, America recycles only 10% of its garbage, incinerates 10% and deposits a whopping 80% in landfills. As a result, it is having to cope with a monumental solid waste problem.

Our landfills are going–going–gone.

Americans throw away about 160 million tons of garbage a year. Of that total, plastics make up less than 8%, paper about 36%, and glass and metal about 20%, all by weight. Plastics are naturally lighter, but still, when compressed account for only about 20% by volume.

As a result, in the past 10 years our country's landfills have decreased from about 18,500 to 6,000. In five years 2,000 more will close.

In their haste to find solutions, some local legislatures have proposed to ban plastics.

Unfortunately, a ban on plastics would do much harm and no good. We would lose all of the safety, health and convenience features of plastics such as tamper-resistant closures and shatter-proof bottles.

Moreover, packaging would still be needed. A 1987 study shows what would happen if plastics were banned—the energy needed to produce the alternative packaging, its weight, its cost, and the volume of waste collected would all rise dramatically.

What to do?

At Amoco Chemical, we believe part of the answer to America's waste problem lies in recycling everything from glass to metals to paper to plastic.

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Right now, almost 200 companies are recycling millions of used plastic containers into paint brush bristles, traffic signs, toys, floor tiles, wastebaskets and "plastic lumber" for decks and park benches.

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Show Me the Way You Go Home

Researchers are still asking how homing pigeons do it

by Charles Walcott

Racing pigeons taken from their home loft and released up to a thousand miles away in unfamiliar territory return home. How do they know which way to fly? This deceptively simple question has kept research groups in Germany, England, Italy, and the United States busy for more than four decades.

I believe that the reason this straightforward question is so hard to answer is that we have greatly underestimated the abilities of pigeons. The ancestors of our pigeons were probably the wild rock doves of the Mediterranean area. They nested on cliffs, but being grain eaters, they had to feed both themselves and their young by foraging extensively over fields. Presumably, the ability to home came from the need for a dove to return to its mate and young with food. City pigeons still cling to this ancestral pattern, but substitute bridges and buildings for nesting cliffs and scavenge in parks and city streets for scraps instead of foraging for natural grains.

Because they learn quickly, pigeons are common inhabitants of psychology laboratories. Here they are used not only to study the process of learning but also to demonstrate to students how sensory abilities are measured. Despite the number of pigeons tested for their hearing, vision, and other sensory capabilities, much remains to be learned. In the past, psychologists assumed pigeons' sensory abilities must be much like humans', but perhaps more limited. Only when pigeons were viewed without preconceptions did interesting results begin to come in. For example, in 1977, Marilyn Yadlowski, an undergraduate at Cornell University, found that pigeons had excellent low-frequency hearing, far surpassing that of humans. This finding was followed up by Mel Kreithen, now at the University of Pittsburgh, and by Doug Quine, now with Martin Marietta. Doug showed that pigeons are able to hear sounds as low in frequency as 0.1 Hz; that's one cycle every ten seconds. In addition, Mel Kreithen showed that pigeons are exquisitely attuned to changes in atmospheric pressure. They also can see in the ultraviolet, are sensitive to changes in light polarization, and can detect ground-borne vibrations. At Harvard, Richard Herrnstein and his colleagues have demonstrated that pigeons have an extraordinary visual memory. Trained on several hundred slides of common Cambridge scenes, pigeons can remember, even some months later, which pictures were coupled with the reward of a pigeon pellet. The pigeon is a more impressive animal than many of us thought, and one difficulty in understanding how a pigeon homes may be that we have been looking for too simple a mechanism or too neat an answer. Homing pigeons may instead rely on multiple cues.

We have learned a lot about pigeons since I last wrote for *Natural History* in 1972. For example, it turns out that pigeons have two systems for finding their way home: in one, they use the sun as a compass, allowing their internal clocks to compensate for its apparent movement through the sky. But when the sun is not visible, they make use of the second system, the earth's magnetic field. Furthermore, German researchers Rosie and Wolf Wiltschko report that young pigeons have to learn to use the sun compass. They apparently calibrate it against their magnetic compass during early training flights. This is curious. Why would a pigeon not continue to use a magnetic compass, useful in both sunlight and under cloud cover, rather than learn the trick of interpreting the movement of the sun? Nobody seems to know. But a compass alone is not enough to get a pigeon home. A compass simply indicates direction—north, south, east, or west; it doesn't tell you where your home is. The homing pigeon, once released, needs to know something much more complex—its location relative to its home loft. In analogy, imagine yourself in a compass-equipped boat on the open ocean. Which way do you steer in order to reach home? Everything depends upon where you are and where you want to go. Once you have figured out that you need to go west to find home, the compass will point you in that direction. The position-finding problem—"which way is home?"—is called, in homing studies, the map. The sensory basis of this map is what we seek to understand.

Working with homing pigeons is not hard, but the procedures are tedious. As soon as young pigeons are able to fly, a handler trains them by releasing them at increasing distances from the loft. Generally, this follows a period of free flight around the loft itself. The birds are then released as a flock at increasing distances, say one, five, ten, twenty, thirty, and fifty miles along a line away from the loft. After they are able to return promptly from fifty miles away, they are released singly ("tossed," in homing parlance) at short distances to build up their enthusiasm for flying alone. When pigeons are returning well from single tosses they are ready to be used in experiments.

In a test, pigeons are taken to the release point, usually in a covered basket and then released one by one. Each pigeon is watched with 10 x 50 binoculars until it disappears from sight in a direction called, without much imagination, the vanishing direction. When we cannot watch the pigeons directly, we attach tiny radio transmitters to their backs and follow the signals. The direction in which the radio signal fades is called the radio vanishing bearing. Finally, pigeons equipped with radios can also be followed by direction-finding equipment mounted in an airplane. Years ago I spent several thousand hours flying all over New England after radio-equipped pigeons; now the same thing is being done at Cornell by some of our visiting investigators.

This kind of research is not without its hazards. On one occasion here in upstate New York, an irate farmer accused us of adding to the nuisance pigeon population in his barn. We pointed out that our pigeons were pedigreed racers quite diffe

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ent from the common variety and would promptly fly back home. This explanation would have had more force if the next pigeon we released hadn't flown slowly and carefully down to land on the roof of the farmer's barn. On another occasion I drove to a favorite release site only to find that the fire tower from which I had accumulated twenty years of data had just been removed. I've followed pigeons by airplane only to find that they are not familiar with federal air regulations and fly happily through Elmira's Air Traffic Control area. The response of the controllers to the announcement that one is tracking a pigeon can be imagined. Then there are the difficulties of keeping the project going with an aging fleet of pickup trucks, summer interns who can't drive standard shift, and student helpers who must be persuaded that they'll love working long hours and shoveling pigeon manure.

Despite these problems we have advanced our understanding of pigeon navigation considerably in the last seventeen years, and three stories can summarize our progress. They could be titled "The Curious Case of Olfaction," "The Mystery of Jersey Hill," and, finally, "On Being Bothered by Magnetic Anomalies."

The olfactory story begins in 1972, when Floriano Papi and his colleagues at the University of Pisa in Italy reported that interfering with a pigeon's sense of smell disrupted its ability to orient and to return home. Over the next few years, the Italian group performed an extraordinary variety of experiments in odor manipulation. The end result was always the same: interference with the pigeons' olfaction resulted in disorientation and in poor or no homing. This led the Italians to suggest that the birds, growing up in a loft, learned to associate the odors carried by the wind with the compass direction of the wind that brought the odors. Another possibility, suggested by Hans Wallraff in Germany, was that stable odor gradients existed and extended over long distances. Perhaps pigeons could use these gradients to find their way. Since these suggestions were made, lively research in many countries has tested the idea of an olfactory-based navigational system. The results have not been as clear as one would like. For example, in Italy, Emilio Baldaccini placed pigeons inside a small "deflector loft" where vertically slotted walls allowed the free passage of air and whose large corner panels deflected the wind. Thus pigeons growing up in this loft sensed that wind actually coming from the north was coming from the east, wind from the east was coming from the south, and so on. Pigeons raised in this loft should have their olfactory map rotated by ninety degrees. And so it was. When these pigeons were released, their vanishing bearings were deflected by roughly ninety degrees from home in the predicted direction. Furthermore, repetition of this experiment in both Germany and the United States yielded approximately the same result. But was the effect really caused by olfaction, as the Italians supposed?

In Germany, Jacob Kiepenheuer demonstrated that pigeons raised in the deflector loft and temporarily deprived of their sense of smell (made anosmic by the application of a local anesthetic to their nostrils) were just as deflected as control birds. Here at Cornell, John Phillips and Jerry Waldvogel, who were graduate students at the time, showed that deflector-loft birds released under overcast skies were not deflected at all. Furthermore, if the panels were altered so that light was deflected in one direction and wind in another, the pigeons released under sunny skies were deflected in accordance with the light cues, not with the wind cues. Does that mean that pigeons don't use olfactory cues? Certainly not. It simply means that the deflector-loft effect in Ithaca was due to deflected light cues, not odors. And it shows how careful one has to be in designing experiments so as not to be misled by uncontrolled variables.

A few years ago, the Wiltschkos did a comparative study in Italy, Germany, and the United States on the effects of making pigeons anosmic. Using precisely the same experimental techniques in the three countries, they found that anosmic Italian pigeons neither oriented nor homed; anosmic German pigeons oriented and homed as well as control pigeons; and the anosmic Cornell pigeons showed more scatter in their vanishing bearings, slower homing, and greater losses than the controls; still they did both orient and home. This led to the thought-provoking idea that different pigeons in different places might be relying to differing degrees on olfactory cues.

In following up this idea, the Wiltschkos thought about the position of their pigeon loft, which was in a garden surrounded by the tall buildings of the university. Maybe pigeons in this loft had no access to normal winds and thus were forced to rely on alternative cues. To test this possibility, the Wiltschkos established a new loft on the roof of the natural history museum, four stories above the garden loft. Pigeons growing up in this rooftop loft had free access to winds and wind-borne odors. Testing these pigeons revealed that they behaved like Italian birds; with no sense of smell, they were poorly oriented. So once again we were forced to consider the importance of the loft and its surroundings in determining what cues pigeons might use in their navigation.

This led in turn to the realization that perhaps we were not dealing with a single phenomenon and that perhaps the varying outcomes reported by each of us working on this problem were the result of using different stocks of pigeons and conducting experiments in different parts of the world. We ought not to be arguing so strongly about who is "right"; maybe we all are! The end of this first pigeon orientation story has not yet been written and more experiments are being designed. The dove of peace may yet resolve one of the most controversial topics in the field of avian orientation, the role of olfaction.

Our second story begins in 1967 when the late William Keeton showed that when pigeons from our loft at Cornell were released at most places, they circled a few times and then headed for home. But there were a number of other release sites where pigeons consistently and repeatedly headed in some other direction. For example, when released at Castor Hill, ninety miles north of Ithaca, pigeons steadfastly headed west, sometimes as much as eighty degrees to the right of the home direction. Pigeons from other lofts also followed the Castor Hill rule, going clockwise of home. Even bank swallows that we caught and banded in Ithaca and then released at Castor Hill showed the same deflection as Cornell pigeons. Equipping the pigeons with small radio transmitters and following them by plane revealed that they flew about fifteen miles to the west, then turned south and headed directly for Ithaca.

But seventy-five miles west of Ithaca was a more unusual site—the Jersey Hill fire tower. Cornell pigeons released here for the first time generally vanished to the southwest and only a small fraction ever made it home. If those birds that did make it home were released at Jersey Hill for a second time, their vanishing bearings were totally random and few returned. Jersey Hill proved to be a Bermuda Triangle for our pigeons.

But does Jersey Hill spell disaster for all pigeons? Laurimore McConnell is a well-known and successful pigeon racer living near Rochester, New York. As president of the American Racing Pigeon Union he had been helpful to us on many occasions, so we approached him with some hesitation about borrowing some of his pigeons to try at Jersey Hill. We explained the hazards of this ominous place and the possibility that he would never again see some of the members of his many-thousand-dollar pigeon race team. A courageous man,

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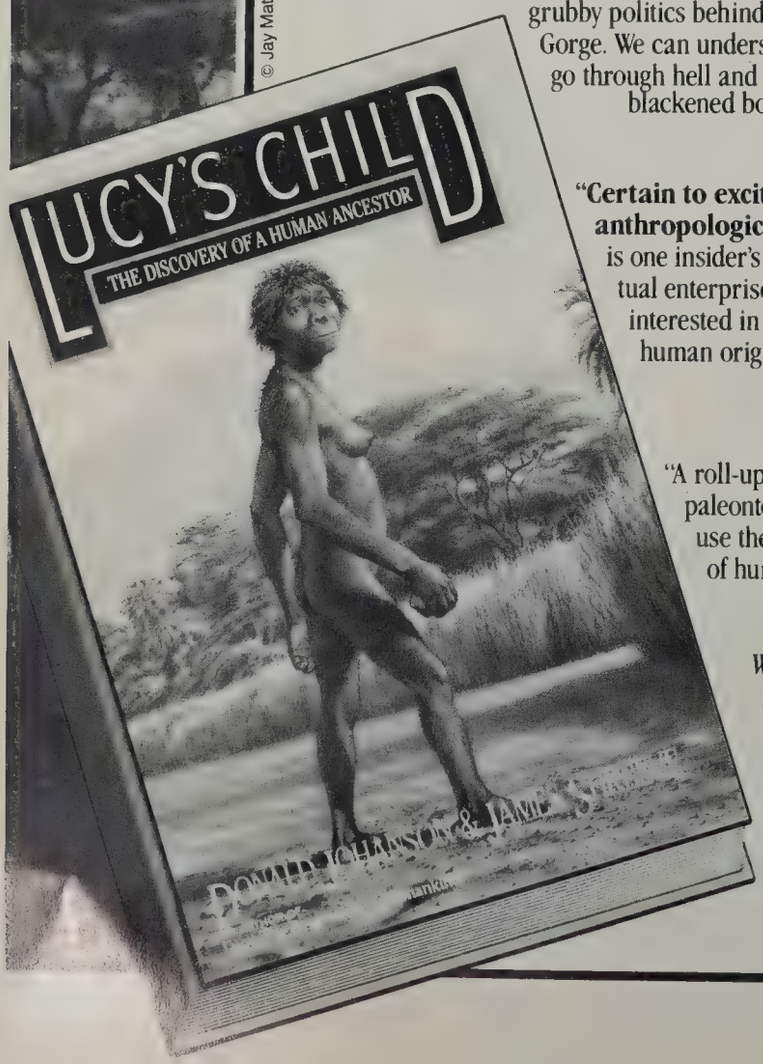

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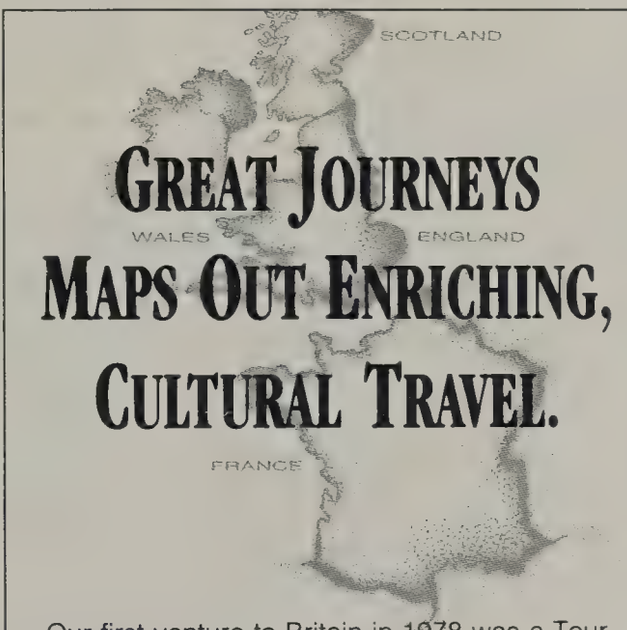
Lauri replied that if his racers couldn't home from Jersey Hill, he didn't want them. With considerable trepidation we released a dozen of Lauri's best birds alternately with a dozen of our Cornell birds. The Cornell birds were their usual muddled selves, but we were greatly relieved to watch Lauri's birds as they headed directly north to their home near Rochester. All but one of Lauri's birds arrived home on the day of release; only one of the Cornell birds made it to Ithaca.

So it appears that not all pigeons are bothered by Jersey Hill. Encouraged by the results with the McConnell birds we began in wanton fashion to borrow pigeons from a number of other racers living at various distances and directions from Jersey Hill. In all cases their birds were well oriented and homed normally. And so it was that our reputation among pigeon racers started foundering. What was the problem with Cornell birds? Was it related to academics trying to do research without a long apprenticeship as pigeon racers? Was it due to the genetic stock of the pigeons owned by Cornell? Or finally, was it because the pigeons were being raised in our loft in Ithaca, New York?

On another occasion, Lauri McConnell lent us some of his valuable breeding stock, close relatives of the birds that had successfully homed from Jersey Hill. We took the young, Cornell-born offspring of these birds and tested them at Jersey Hill. Alas, they did no better than any other Cornell pigeon, regardless of pedigree.

In collaboration with another pigeon-racing enthusiast, John Reenstra of Wayne, New Jersey, we ventured one step further into the mystery of Jersey Hill. We swapped a group of young Cornell birds for a group of young New Jersey pigeons. Because pigeons typically have two young at a time, we could easily arrange a nicely controlled sampling of both groups; we simply traded one of each pair of young birds so that each pigeon had a nestmate growing up and being trained in the other loft. Now we could compare closely related birds of the same age that were reared in different locations. The results of Jersey Hill tests were striking: birds of whatever stock that were raised at Cornell were disoriented, and, conversely, all the birds raised in the Reenstra loft were well oriented toward their loft in New Jersey. We have continued our assault on Jersey Hill with birds from lofts closer to Ithaca and have found that even pigeons raised in lofts fifteen miles from Ithaca can orient and home without any problems. The outcome of these investigations has led us to suspect that whatever terror lurks at Jersey Hill resides only in the feathered heads of pigeons raised at Cornell University.

Pigeon story number three begins with my pre-Cornell research on pigeon homing. I began to investigate this subject in 1962 while on the Harvard faculty. Our first pigeon loft was in the ivy-covered building of the biological laboratories, in Cambridge, Massachusetts, but we soon moved it to Fox Ridge Farm, an estate ten miles to the west, in Linden, Massachusetts. This was wonderfully convenient because I lived, as is fitting for a behaviorist, in a converted pigsty/chicken coop and could tend the birds before going to work in the morning. In the course of many summers of pigeon releases, we found that our birds were disoriented when we released them at places where the earth's magnetic field was disturbed by underground iron deposits—so-called magnetic anomalies. As mentioned earlier, pigeons have two compass systems; they use the sun when it is available and appear to use the earth's magnetic field when the sun is obscured by clouds. The exciting finding at magnetic anomalies was that the disorientation we saw there occurred on sunny days when pigeons should be using their sun compasses. Furthermore, by the best pigeon rules of the decade, the degree of the distortion of the magnetic field at the anomalies we were using should have deflected a magnetic compass by only a few degrees. So we believed that the disori-



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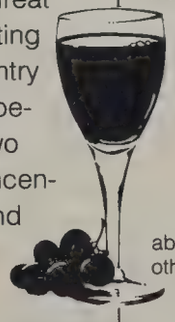

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entation of pigeons at anomalies meant that their position-finding system, their "map," depended in some way on the earth's magnetic field. We were also encouraged when the pigeons proved to be more disoriented at strong anomalies than at weak ones. This evidence was good stuff, good enough to write about, which I did in several learned papers.

At this point, I was offered a position at Cornell University and the Massachusetts pigeons were moved to Ithaca and joined their colleagues in the Cornell lofts on Turkey Hill Road. The old Fox Ridge Farm lofts were converted to other uses, new tenants were installed in the remodeled cottage, and I moved into more conventional habitation. Now that the magnetic anomalies were 250 miles away we looked for the nearest suitable site. As indicated on aeromagnetic maps, it was about 100 miles north of Ithaca, near the little village of Carthage, New York. Not only was this a good hundred miles closer than the anomalies in Massachusetts, but we also had the enthusiastic help of local pigeon racers. A perfect site, we thought.

One group of Cornell birds was released at the Carthage anomaly, while another group was released at a control site outside the anomalous area. To our great surprise the birds released at the magnetic anomaly were better oriented than those released outside of it. Was the problem with the Cornell pigeons or with the Carthage anomaly? Despite reassurances from geologists that one anomaly is much like another, we thought it would be profitable to examine this question first. So we next took Cornell birds to the tried and true Boston anomalies.

Undaunted by the change of venue, the Cornell pigeons didn't seem to mind the distorted magnetic fields in Massachusetts any more than the ones they had experienced in New York; they were not only nicely oriented but some actually made it all the way back home to Ithaca.

Well, we thought, maybe pigeons had to grow up and be trained in Massachusetts before they learned to recognize a distorted magnetic field when they saw one. In an attempt to see if this was so, we reestablished a small loft in Lincoln, Massachusetts. With the Fox Ridge Farm site unavailable to us at this time, we were happy to get permission to raise our pigeons at Codman Farm, only a mile and a half northwest of the original loft of my pre-Cornell days. We stocked the Codman loft with young Ithaca birds, along with some young birds donated by Boston racers. When the Codman team was old enough, it was trained as my birds had been before and then was tested at the old magnetic anomalies. The nightmare of any published author now began to appear: to our horror, all the Codman pigeons were significantly oriented at our two "best" anomalies, those that in years past had confounded the best Boston homing pigeons and about which I had excitedly written. At a third, but weaker, anomaly, the Codman Farm birds were about as poorly oriented as were the Fox Ridge Farm birds of old.

Perhaps, we mused, what is important to a pigeon happens early in life while it is still a tiny embryo or maybe just as it emerges from its shell. Maybe some form of secret pigeon wisdom is imparted to the youngster at a tender age by its experienced, caring parents. The next step led us to breed Cornell pigeons in the Codman loft, thus giving this new group of test birds every possible opportunity to learn all there was to learn about magnetic anomalies. Sadly, this too proved to be of no value in resolving our dilemma. Codman loft homing pigeons, whether imported from Ithaca or raised in Lincoln, remained incorrigibly oriented at our trusty magnetic anomalies.

And that's what brought me on bended knee and with tears in my eyes to approach my former landlord who, unable to resist such an appeal, graciously gave permission to install a small, portable pigeon loft only a hundred yards from the old site at Fox Ridge Farm. In 1988 a marauding raccoon decimated the flock of young pigeons we had stocked in this loft. Replacements were rushed in from Ithaca, but the number of Fox Ridge Farm birds available for testing was small. Those that were released at magnetic anomalies, however, were gratifyingly as distorted as the old Fox Ridge Farm birds had been before. Flown on the same day, the Fox Ridge Farm birds were totally disoriented, while the Codman birds continued to ignore the distorted magnetic information found at the anomalous sites. Although we are desperately hoping for a larger sample this year, the preliminary results have helped to reassure us of the credibility of the magnetic anomaly story.

If Fox Ridge Farm birds continue to be disoriented at anomalies, the biggest surprise of all will be the difference we found in the orientation of birds of the same stock raised in identical lofts only a short distance apart. Why should one group be disoriented by anomalies and the other not? At this writing, we don't know. But looking at the magnetic map of the Lincoln area we discovered an intriguing clue: the Fox Ridge Farm loft is situated in an area of a steep magnetic gradient, whereas the Codman Farm loft is in an area of relative magnetic calm. Might young birds growing up at Fox Ridge Farm learn that the great changes in the magnetic field around the loft, changes that they sense on their exercise and training flights each day, might contain useful navigational information, whereas the Codman Farm birds, deprived of similar magnetic topography, are forced to rely on something else?

On reflection, my three stories seem to tell us that pigeons growing up under different conditions may learn to use different strategies; that Cornell pigeons may be using different cues than Italian pigeons or even Fox Ridge Farm pigeons. It suggests that pigeons are opportunists. An analogy would be that someone growing up in New York City would rely on the pattern of streets and skyscrapers to find his or her way around, while someone raised in Ithaca, New York, might use the pattern of hills and lakes. In short, I believe that we have underestimated the pigeon's ability to choose and use directional cues found in the natural environment and that under different circumstances pigeons can make different choices. This idea, if correct, would go a long way toward resolving the controversy of whether olfaction or magnetism is *the* answer.

But these findings raise another interesting question. One of the reasons for working on homing pigeons is to try to understand how migratory birds find their way on their enormous yearly journeys. If pigeons have a diversity of strategies, could this also be true of migratory birds? Within a single species, do different birds growing up in different environments select different navigational cues?

Many years ago, upon demonstrating that in the absence of the sun homing pigeons make use of magnetic information, Bill Keeton proposed a navigation system based on a redundancy of cues. Since that proposal, we have learned that the pigeon senses a world quite different from ours—a world of pressure changes, infrasonic sounds, polarized light patterns, ultraviolet light, subtle vibrations, naturally fluctuating magnetic fields, and perhaps other cues yet to be discovered. Given the limitations of our own sensory world and our bond to the earth's surface, solving the mystery of how pigeons find their way is indeed a challenging and intriguing goal. The humble homing pigeon, in a way, is a window enabling us to look out at a mysterious world.

Charles Walcott is a professor of biology at Cornell University, Ithaca, New York, and executive director of the university's Laboratory of Ornithology.

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Return of the Mighty Muskox

A common sight and frequent meal for our Ice Age ancestors, this hardy grazer of the tundra reached a low ebb in the early 1900s

by Peter C. Lent

Nearly twenty years ago, five large and hairy immigrants arrived unexpectedly in the Härjedalen area of west-central Sweden. Their like had not been seen in Sweden since the Pleistocene, 12,000 years ago. The tourists that flock to this area are all in favor of the immigrants and their descendants, who now number more than forty, but the local Saami reindeer herders are not so sure. For these shaggy newcomers are muskoxen, and the Saami fear they will compete for forage with their domesticated reindeer.

The Swedish experience is not unique. Throughout the northern circumpolar lands, muskox populations have been growing, often at surprisingly high rates, and with help from humans, the species has greatly expanded its range. The muskoxen that showed up in Sweden in 1971 had traveled 150 miles from the Dovre Mountains of Norway. Descendants of animals brought into Norway between 1947 and 1953, they were vivid proof of the species' ability to weather the trials of introduction and then move on to new territory.

During the Ice Age, muskoxen ranged as far south as Iowa, in North America, and northern Spain, in Europe, but in recent centuries, the species has been confined to arctic tundra habitats, such as Greenland and the arctic islands of

Erwin and Peggy Bauer

Erwin and Peggy Bauer

Canada (although on the Canadian mainland, they live in the northern fringes of the boreal forest). Unlike their fellow grazers, the caribou, which often migrate long distances to favorable winter habitats, muskoxen stay on these sparse rangelands year-round. The muskox is a relatively nonselective feeder but does seek out the best habitats around, usually along streamsides. In the summer, riparian shrubs and lush grasses provide a rich diet, but in winter, these plants may be buried under deep snow. Although the true Arctic actually receives only a moderate amount of snow, strong winds distribute it unevenly, exposing the less productive uplands and filling depressions along streams.

The same strong winds that move the snow around conspire with winter temperatures of -30° F or colder to subject muskoxen to a harsh environment. The

Tony Martin, Oxford Scientific Films

Two muskox bulls, left, molt their insulating underhairs in long, ropy patches. Below left: Animals from the Nunivak Island population walk near the edge of the Bering Sea ice pack. Death may await any that venture out on the unstable offshore ice. Below: Agile climbers, muskoxen sometimes seek out the rich clumps of grass that dot rocky cliffs.

Fred Bruemmer

animals' most obvious defense against the cold is a long, flowing curtain of coarse guard hairs. Underneath lies insulating underhair of fine, cashmerelike fibers. Most muskox calves are born in May, but some arrive as early as April. For them, survival depends on this insulative coat, which even extends down their legs, and on exceptionally high metabolic heat production. In a tundra environment with few windbreaks, the calves also seek shelter next to their big mothers.

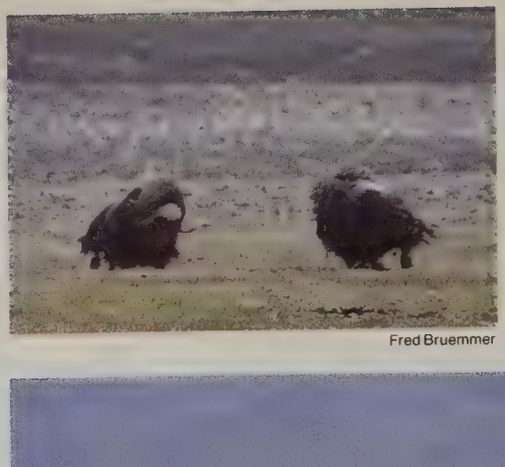
But ability to cope with its harsh environment and a well-developed defense strategy against wolves (typically a tight shoulder-to-shoulder huddle, heads facing out) have not always been sufficient to assure the muskox's survival. The species has not fared well in its long history of interactions with humans, for while huddling together may be effective against wolves, it actually increases the muskoxen's vulnerability to human hunters, even those armed with simple spears. Hunters with dogs are especially dangerous, for muskoxen respond to dogs as they do to wolves, bunching tightly and thus making themselves easy targets.

Ten thousand to 12,000 years ago, muskoxen were the subjects of hunter-artists of northern Europe. From southwestern Russia to the Pyrenees Mountains, the grand cave art of the period shows muskoxen among reindeer, wild horses, bison, and the hunters themselves. Muskoxen were also depicted with stunning beauty and accuracy in small sculptures and in delicate figures engraved on bones and antlers. Obviously, the muskox was of interest to these flourishing hunter cultures, presumably for its excellent meat. Much evidence, including observations of early explorers, exists that concentrations of hunting peoples were able to wipe out muskox populations locally even before the use of firearms, so it seems likely that, along with post-Pleistocene climatic changes, humans had a role in the disappearance of the muskox from northern Eurasia. Similarly, the coastal Eskimo in northern Alaska, using dogs and aboriginal hunting weapons, could have extirpated the muskox without guns.

Muskoxen hung on in isolated arctic habitats, but in the nineteenth century, they declined rapidly even there, their numbers devastated by the armed enthusiasm of explorers, whalers, fur traders, and Eskimo. By the early part of this century, the species had reached a low ebb of an estimated 11,000 individuals, only a fraction of their former number.

By the 1930s, prohibitions on hunting of muskoxen existed everywhere. The number of animals began to increase slowly at first, then more rapidly, and by the 1960s a muskox success story was beginning to unfold. As it turned out, biologists had greatly underestimated the species' ability to rebound. In the first half of the century, the prevailing concept of muskox reproductive biology was that a female would rarely, if ever, give birth in the wild before the age of four and that thereafter she would typically produce a single calf every other year. Based on this concept, population ecologist P. H. Leslie calculated in 1965 that "the intrinsic rate [of increase] cannot be greater than a figure between 8 and 15 percent a year." He went on to state that under most circumstances, the rate would be at or below his lower figure.

How the idea of calving in alternate years—now known to be erroneous—orig-



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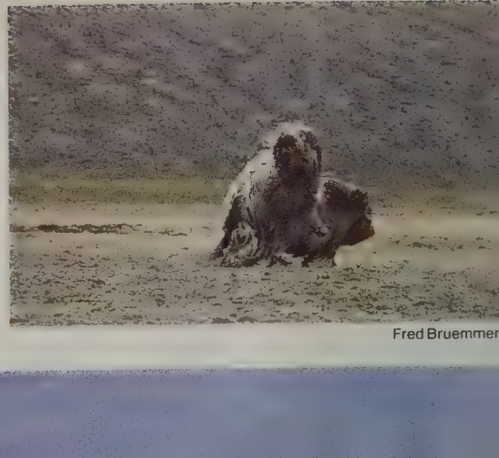

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inated is not entirely clear. In the summer and through the September rutting season, muskoxen congregate in small groups of cows, yearlings, and calves, together with one adult male. Occasionally, as early observers noted, these groups may lack calves. The assumption was that a female could not come into estrus until her yearling offspring was weaned. Cause and effect were being confused, however. A more likely scenario—and one common among ungulates—is that cows without calves, having failed to conceive or having lost a calf soon after birth, had allowed their yearlings to remain with them and maybe even to suckle.

New information coming out of Alaska was to change many more ideas about muskox reproductive biology and population dynamics. The species had previously ranged, although apparently never in great abundance, across the arctic tundra zone north of the Brooks Range. Sometime between 1850 and 1870 the last muskox was killed by Eskimo hunters. In 1929, the U. S. Congress appropriated funds to bring the muskox back to Alaska and possibly domesticate it. Thirty-four calves were captured for this purpose in East Greenland. Right from the start the animals demonstrated their adaptability and hardiness. First, they were taken by boat to Europe, where they were held for several months. Then they were shipped to New York City to be held in quarantine for an additional month. From there it was on to Seattle by railroad and then another boat trip to Seward, Alaska. In Seward they were loaded onto railroad cars for the final 800-mile trip to Fairbanks. All survived and were released in newly fenced pastures in September 1930.

By 1935, however, congressional interest (and funding) had waned. In addition, fencing had proved hard to maintain, and several young animals had been killed by black bears. A decision was reached to turn the animals loose. Nunivak Island was selected, for several reasons. The island is separated from the mainland by only twenty-three miles, so transporting the animals would not be a problem. Also, it had plenty of good forage, or so it was thought, and no predators. In the summers of 1935 and 1936, a total of thirty-one muskoxen, including many of the original stock, plus a few born in captivity in Fairbanks, were shipped by barge down the Yukon River and across to Nunivak.

Wolfgang Bayer

The thirty-one animals left on the 1,700-square-mile island increased slowly over the next decade or so, but sometime after 1947, the pace picked up, with population growth averaging more than 16 percent annually. By the late 1960s, Nunivak was home to more than 700 animals, but one flaw of the island—overlooked by those who had put the muskoxen there—became increasingly evident: the island is not in the Arctic. Its climate is cool, maritime. Heavy winter snowfall and frequent freezing rains result in a snow cover of three feet or more, often laced with layers of ice, over much of the island. Most of the abundant forage is unavailable in winter.

My own involvement with muskoxen began on Nunivak Island in 1969. The general public and the decision makers in government were not yet convinced that a problem was developing on the island. I was asked to conduct studies of range use and muskox population status to supplement the extensive data already collected by the Nunivak National Wildlife Refuge staff. By compiling data from my own surveys and those of others, I showed that during winter, muskoxen were foraging on less than 5 percent of the island. Initially the small population had wintered on small, windblown tundra areas at the top of escarpments on the west end of the island. As the population grew, its increasingly heavy use of coastal sand dunes along the south shore caused great concern. Onshore winds kept the tops of these dunes relatively snow-free throughout the

Below: Muskoxen can run surprisingly fast, but tire easily. Far left: Two big bulls charge each other in a rutting-season contest. Left: The dominant male gets a chance to mate.

winter, and in spring the dunes' south-facing slopes were the first areas on the island from which snow melted. The muskoxen were not only feeding heavily on the dunes' principal plant, a tall, coarse beach grass, but they had also created an extensive system of trails along the crests of the dunes, where winter travel was easiest. The dunes were starting to collapse; large, saucer-shaped blowouts were becoming alarmingly common.

At that rate, these dunes, so unusual in northern lands, would lose their vegetative cover. And even over the very short term, the dunes weren't the answer to the muskoxen's problems. More animals were dying every winter. In 1972 and 1973, my assistants and others located twenty-six carcasses of animals that had died in winter. An analysis of marrow fat in the femurs of fifteen of these carcasses showed that about half were in a state of severe malnutrition at the time of death. The dead were mostly young to prime-age animals, three to eleven years old.

The stresses of winter did not, however, appear to slow the survivors down much reproductively. Calf production had declined somewhat in the 1960s as the population approached its peak, but many females were continuing to give birth to calves in successive years, even as the winter-range problems were developing. Most pregnant females seemed to fare relatively well in the competition for the limited winter range. Then, after giving birth in the spring, they apparently benefited so much from the abundant summer forage that, despite the demands of a nursing calf, they were in good enough condition by the fall to come into estrus.

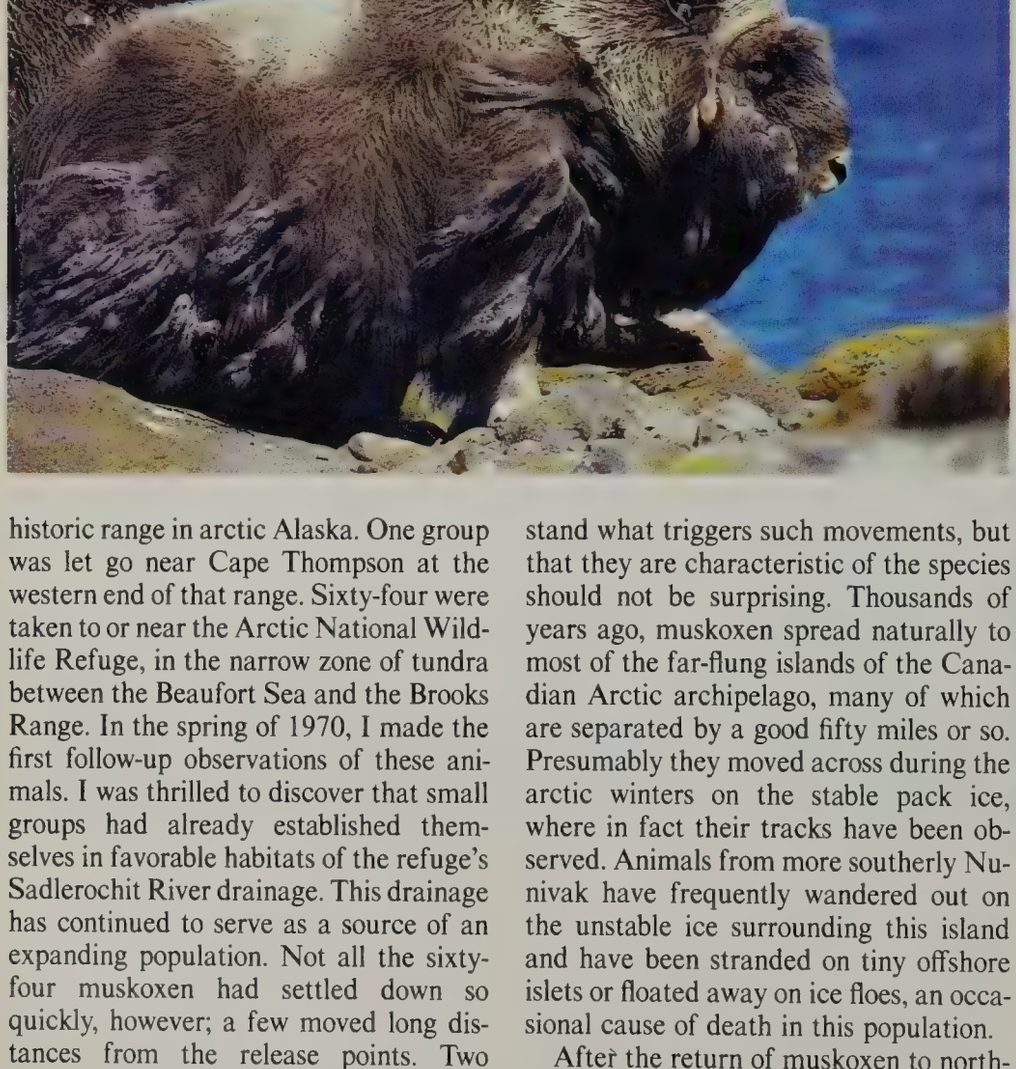
In 1967 and 1968, prior to the completion of studies on Nunivak, the Alaska Department of Fish and Game and the U. S. Fish and Wildlife Service had undertaken two small-scale transplants, taking a total of twenty-three muskoxen from Nunivak across to nearby Nelson Island. This release site was chosen primarily for reasons of proximity and economy. Although it was technically an island, the area was separated from the Alaska mainland only by narrow channels that would provide no obstacle to the future dispersal of muskoxen. Like Nunivak itself, Nelson Island was not known to have had muskoxen in the past.

Following the success of these trial transplants, and in response to mounting evidence of overpopulation on Nunivak Island, the agencies removed more muskoxen from the island in 1969 and 1970, this time releasing them on their

Stephen J. Krasemann; DRK Photo

A male muskox, below, has a somewhat rounded snout, while females, such as the cow with young calf at bottom right, have a slightly dished face. On Canada's Banks Island, right, a loose-knit group of muskoxen, including calves and adults of both sexes, browse in midsummer.

Sue Matthews; DRK Photo



historic range in arctic Alaska. One group was let go near Cape Thompson at the western end of that range. Sixty-four were taken to or near the Arctic National Wildlife Refuge, in the narrow zone of tundra between the Beaufort Sea and the Brooks Range. In the spring of 1970, I made the first follow-up observations of these animals. I was thrilled to discover that small groups had already established themselves in favorable habitats of the refuge's Sadlerochit River drainage. This drainage has continued to serve as a source of an expanding population. Not all the sixty-four muskoxen had settled down so quickly, however; a few moved long distances from the release points. Two headed east into the Yukon Territory, reaching almost to the Mackenzie River. Another moved south over the crest of the Brooks Range, traveling more than 150 miles, almost to the Yukon River, before being shot by an Athabaskan Indian hunter. (The hunter had never seen a muskox and later explained that in the poor light he had mistaken this animal, with its rolling gait and long hair, for a grizzly bear.)

As the 1971 migration from Norway to Sweden showed, even muskoxen in long-established populations occasionally undertake long journeys. We do not understand what triggers such movements, but that they are characteristic of the species should not be surprising. Thousands of years ago, muskoxen spread naturally to most of the far-flung islands of the Canadian Arctic archipelago, many of which are separated by a good fifty miles or so. Presumably they moved across during the arctic winters on the stable pack ice, where in fact their tracks have been observed. Animals from more southerly Nunivak have frequently wandered out on the unstable ice surrounding this island and have been stranded on tiny offshore islets or floated away on ice floes, an occasional cause of death in this population.

After the return of muskoxen to northern Alaska, one vast segment of the Arctic remained without them: the Soviet Union. Some Soviet biologists believed that muskoxen had persisted in Siberia until as recently as 200 years ago, and for many years Soviet nature enthusiasts and biologists alike had written about, and hoped for, the reestablishment of this species in their northern areas. Finally, in 1972, during the warm glow of East-West détente, the U. S. government agreed to give the Soviet Union muskoxen from Nunivak Island. Forty of the animals were captured and flown by small aircraft across to a larger airfield in Bethel, Alaska. Here, in April 1975, for the first time since World War II, a Soviet aircraft landed in Alaska. From Bethel the Soviet cargo plane took the animals across to Cape Schmidt where they were divided into two groups. Half went to the Taimyr Peninsula, a vast tundra area in north-central Siberia. The rest went to Wrangel Island, a nature reserve famous for its polar bears, in the Chukchi Sea off the northeast corner of the USSR.

The techniques used to capture and translocate muskoxen to the Soviet Union represented considerable refinement over those of prior transplants. Up through the 1930s, all muskoxen were transported by ship and in the summer, when waterways were open. The earliest techniques could be ruthless. Dogs were used to bring a group of muskoxen into a defensive position, and the adults were then often shot so

that calves could be safely captured by hand. Later, because of the threat of predators around the release sites, transplants to northern Alaska included some adults, anesthetized for safety. The more recent Alaska transplants have also all been conducted in the wintertime, the modern snowmobile being a rapid and reliable method of getting to herds and taking captured animals, tied onto sledges, to a holding facility or airstrip. For the transplant to the Soviet Union, only animals two years old or younger were captured because the animals were initially to be held in fenced areas and protected from potential predators. Drugs were thus not required. The Eskimo of Nunivak Island wove large nets out of parachute shroud cord and, riding their snowmobiles, used rodeolike skills to separate the young animals from the herds and capture them.

Per Klaesson/Bengt Olof Olsson; Bildhuset

Now that the Taimyr population has increased and includes adults, the animals are able to defend themselves and have been released to roam freely.

A few of the earlier transplants failed (notably in Iceland and Spitzbergen), but more recent ones have confirmed the newfound appreciation of how prolific the muskox can be. In 1969, I conducted an aerial census of the animals released on Nelson Island in the previous two years and found that the number of calves far exceeded expectations. The explanation I arrived at was that one of the young females from the 1967 release had bred as a yearling and given birth at the age of two, something that had not previously been reported from a wild population. Similarly, among the Sadlerochit River animals, for which annual rates of increase of up to 24 percent have been reported, two-year-old females have been observed nursing offspring.

The record for fecundity among individual muskox females comes from Norway. There, Norwegian biologist Einar Alendal learned to recognize animals individually and kept long-term, detailed records of births and deaths. Two of the cows he had records for, Kari and Astrid, were in the group that had moved to Sweden in 1971. At last report, fifteen-year-old record-holder Kari had produced eleven calves.

Despite such prolific females, the Norwegian population has not increased dramatically. Several factors, including the animals' tendency to disperse, may be limiting growth. A few animals have been removed intentionally (one bull was shot after killing a farmer on a bicycle). And in July 1978, a single stroke of lightning in the exposed mountain terrain wiped out an entire group of twelve animals in an instant.

The most impressive population growth has taken place in Greenland. In the early 1960s, a total of twenty-seven muskoxen were taken from East Greenland to Søndre Strømfjord on the west coast, from which the species had always been excluded by the Greenland icecap. Number[illegible] by 1977 and more than 500 by [illegible] population now exceeds 1,500, with annual rates of increase as high as 30 percent. Biologists monitoring this population have observed significant changes in vegetation. Historically, the willow stands of Sarfartoq Valley have been the most extensive and developed in Greenland; now there is concern that muskoxen are damaging the stands. At the same time, the native population of caribou in the Søndre Strømfjord area has been declining, perhaps as a result of competition.

With such success in most of the introduced populations, and with indigenous populations generally thriving as well, muskox numbers have increased worldwide to more than 80,000 today. In Alaska alone, there are now more than 1,500. The time has come to take a new look at the species and our relationship to it. Some changes have occurred already; muskox hunting is undergoing a widespread revival. In Alaska, Canada, and Greenland, native peoples now have the right to hunt certain populations, and pressures exist to harvest additional herds. Limited sport hunting is allowed in Alaska and Canada.

What effect hunting will have on muskox numbers remains to be seen. Other threats include the exploration and development of oil and gas resources in some areas of Canada and Alaska, including the Arctic National Wildlife Refuge, where muskoxen have been so successfully reintroduced. Looked at from a larger perspective, muskox survival is no longer the only issue: the communities into which the species has been introduced must also be considered. A variety of ecosystems in Scandinavia, western Greenland, and western Alaska are now confronted by expanding muskox populations with the potential to alter plant communities and compete with other wild and domestic herbivores. Very little is known about just how, and how much, the muskoxen will affect their environments, but there seems little doubt that, helped by the very species that once contributed significantly to its decline, the muskox has entered a new era. And whatever problems may have to be dealt with in the future, I am glad to have this animal, so evocative of the Ice Age, secure in its tundra home again. □

Muskoxen's typical defense is to huddle together, heads facing out, but as these animals demonstrate, a few individuals sometimes face the wrong way.
Erwin and Peggy Bauer

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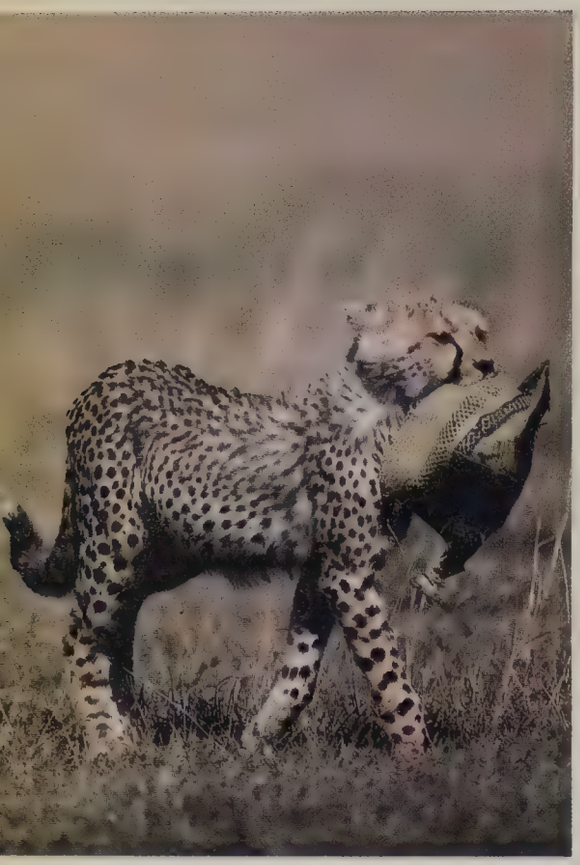
Curiosity Killed the Hat

Text and photographs by Gregory G. Dimijian

We spotted the cheetahs from a low rise on the rolling savanna north of Kenya's Masai Mara Game Reserve. The three cubs were wrestling, and their mother, resting in the shade of some small trees, watched us intently as we approached. My wife, Mary Beth, and I recognized this family as one we had already seen twice during our month in the Mara.

On this August morning, the mother was warily eyeing a tourist van that had sighted the foursome and was parked about a hundred yards away from them. Then the UFO wafted in from the van's direction and landed just twenty feet from the group. The six-month-old cubs eyed the strange object, and as curiosity overcame caution, one of



them moved stealthily toward the intruder, using all of its new stalking skills. Its ears pressed back, the cub stopped short and hissed, then closed in and clamped the strangely passive prey in its teeth.

As the cub started to trot off, ears still pinned, its meddlesome siblings were quick to intervene and a tug of war ensued. Oblivious of their human audience, the young cats tossed, pulled, and pawed the spineless creature for the next hour and a half. Finally they tired of the game, and one young cheetah claimed the tattered prize.

Gregory G. Dimijian is a practicing psychiatrist in Dallas, Texas, and an assistant professor of psychiatry at the University of Texas-Southwestern Medical School, Dallas.

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Birth of the Moon

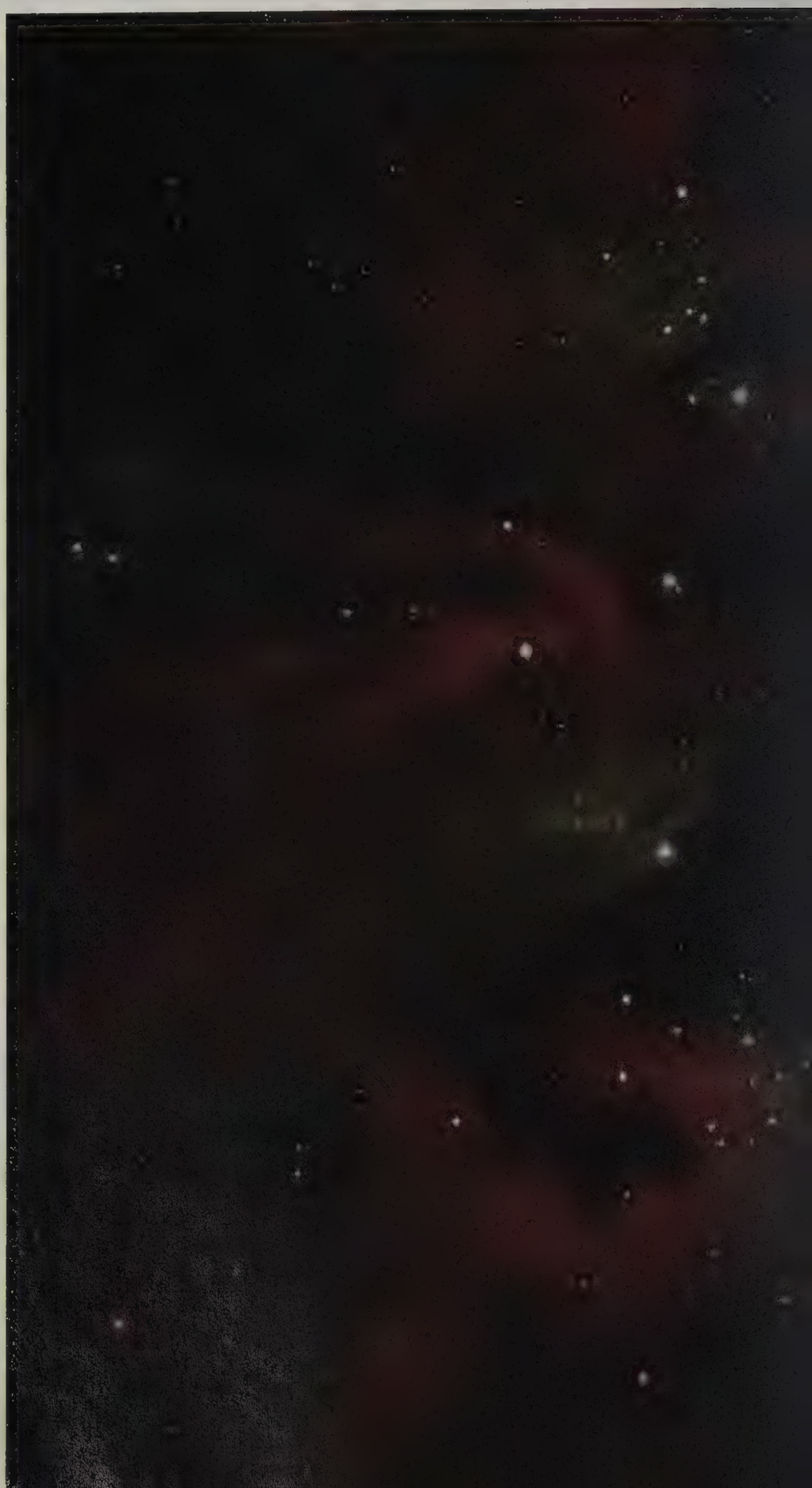
Rejecting past theories, many scientists now believe that our moon originated in a violent collision amid the chaos of the early solar system

Text and paintings by William K. Hartmann

Two hundred years ago, few scientists believed that stones could fall from the sky. Tales of such events were widely branded as superstition until 1794, when Ernst Chladni, a German scientist, published his treatise on meteorites and sparked a lively scientific debate. On April 26, 1803, a fireball appearing in the afternoon sky over the town of Laigle in Normandy settled the question. As it streaked across the sky at high altitude, it exploded, pelting the town with several thousand celestial stones.

The fortuitous Laigle meteorite shower was well documented and convinced most scientists of the reality of these rare events, but the origin of the stones was still far from certain. Some believed that they formed in the upper atmosphere or that they were ejected from volcanoes on the moon. Chladni, however, believed that they were of cosmic origin and probably represented material that, for one reason or another, had never joined the planets during their formation. Only recently, in the age of space exploration, have scientists accurately dated meteorites with radioisotope techniques and proved Chladni right. Most meteorites were formed about 4.5 billion years ago, during the birth of the solar system—a relatively brief period of about 30 million years.

The planets were once thought to have formed from fiery blobs of gas torn out of the sun or from massive clumps of gas left over after the sun formed. But in the 1950s, Otto Schmidt, a Soviet planetologist, argued that if each planet had formed separately from a single blob, their motions would be more random; some planets would travel in highly elliptical orbits and in different directions. They would not spin in the same direction, and their axes would be randomly tilted. As Schmidt pointed out, the solar system is, instead, quite orderly: with few exceptions the planets all travel in concentric, nearly circular orbits in the plane of the sun's equator; revolve in the same prograde direction (counterclockwise as seen from above the north pole); and spin on their axes in the same prograde sense, with little tilt, so that the planets appear as tops, spinning upright. Schmidt was the first to



Surrounded by traces of the interstellar nebula from which it came, the newborn sun shines in the center of a thin disk of dust and gas. Our solar system originated from this leftover material revolving around the sun. Such planetary disks have recently been detected around several young stars.

develop compelling arguments that these regularities could be explained only if the planets formed from countless smaller bodies. As matter condensed out of the thin disk of hot gas and dust revolving around the new sun, it coalesced into larger particles, just as snowflakes stick together as they fall. In a relatively short time, perhaps a million years, the tiny grains aggregated into mountain-sized bodies called planetesimals. If a growing planetesimal was shifted into an elliptical orbit, it would cross the paths of others and eventually be destroyed in a collision with another planetesimal or be nudged by gravity back into a path parallel with its neighbors'. A few large planetesimals came to dominate the solar system—the embryos around which the nine planets grew. This general theory of aggregation, now widely accepted, explains many features of the solar system—but not all.

In our own backyard, the moon has long been an enigma, its origin escaping simple explanation. The satellite is an oddity in the solar system. Mercury and Venus lack satellites. Mars has two tiny moons, but they appear to be asteroids captured from the nearby asteroid belt. The giant planets Jupiter, Saturn, Uranus, and Neptune resemble scaled-down solar systems, each with a large mass and many tinier worlds revolving around it. Why does Earth have just one moon with a diameter one-quarter that of its own?

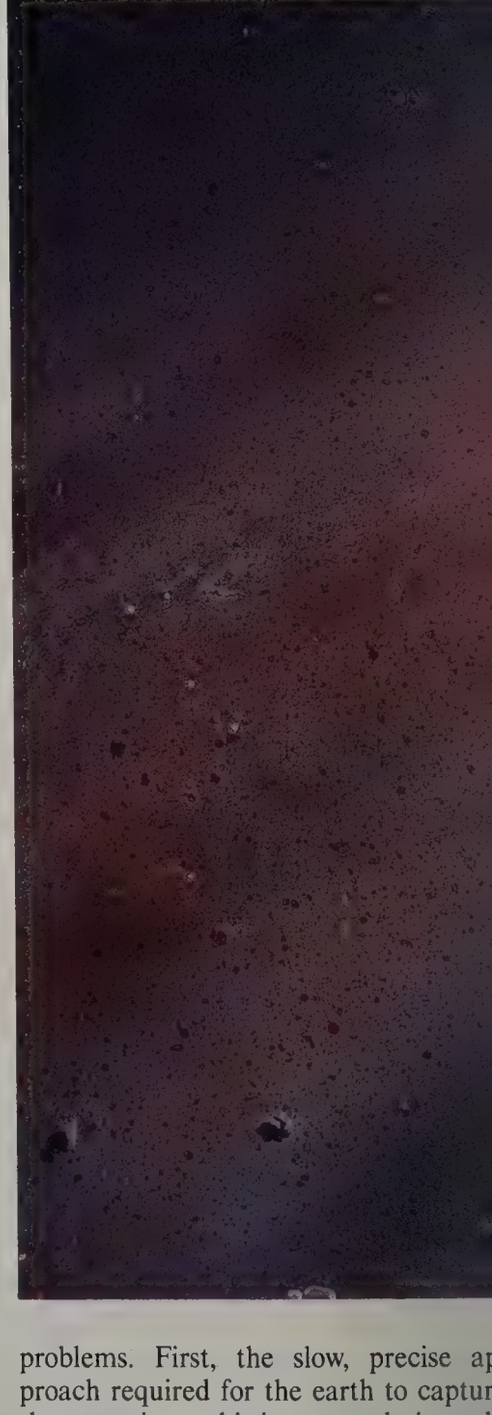
In the late 1960s, with the Apollo program about to land the first men on another world, the question of where our moon came from grew in prominence, and solving it became one of the main justifications for traveling to the moon. Long before Apollo, three main theories of lunar origin had been proposed. In the days before widespread feminist sensitivities, a (male) NASA scientist named these the sister, daughter, and pickup theories. According to the sister theory, the moon grew side by side with the earth, perhaps starting as a relatively small planetesimal in the earth's orbit and attaining its present size by gradually accumulating enough of the rocky material falling toward the earth. The daughter theory suggested that the moon was a spinoff: the earth began to rotate so fast that it became unstable, and tidal forces from the sun tore the moon away from a great bulge at the equator. The pickup theory proposed that the moon formed in another part of the solar system and was then captured in an orbit around the earth.

The astronauts, who were trained by geologists, combed the lunar surface for rocks that might represent the moon's earliest crust. With these "genesis" rocks in hand, the geochemists back in Houston hoped that they could determine which of the three theories was right. Their optimism faded, however, as soon as the lunar samples were studied. Virtually no genesis rocks were found. One of the few ancient chunks of lunar crust brought back was dated at about 4.44 billion years old. But unfortunately, a heavy bombardment of meteorites during the first few hundred million years of the solar system had pulverized virtually all rocks older than 4 billion years. Those that remained were still older than most rocks on the earth, where active geologic processes have destroyed almost all traces of ancient crust, but they were not adequate to decipher the moon's earliest history.

By the end of the Apollo program, the situation had grown still more puzzling. The chemical composition of the lunar rocks, along with considerations of dynamics, had helped to rule out all three theories. A major problem with the sister theory was that the earth has an abundance of iron, mostly in its core, while the moon has very little. The moon also lacks water or water-bearing minerals. How could the moon have grown next to the earth and missed out on its share of these abundant terrestrial minerals?

The daughter theory had trouble explaining the current angular momentum of the earth–moon system (the momentum stored in the earth's spin and the moon's orbit). It is only a fourth of the angular momentum that the earth would have needed to spin off the moon. And since no easy way exists for the system to lose that much angular momentum, the earth never had the energy to spin fast enough to spawn the moon.

The pickup theory had three major problems. First, the slow, precise ap proach required for the earth to captur the moon into orbit is extremely improb able. The chances of a large planetesima striking the planet or zipping in and out o its gravitational grasp are far greater. Sec ond, like the daughter theory, this on failed to account for the observed angula momentum. And third, materials in di ferent parts of the solar system have di ferent ratios of heavy to light oxygen a oms, while the earth and the moon shar identical oxygen isotope ratios, indicatin



mall bodies, called planetesimals, littered the early solar stem. Initially only grains of dust, they grew larger as they ccumulated matter from the cloud enveloping the sun.

hat they do not come from separate parts f the solar system but from the same asic material, in spite of the moon's iron nd water deficiencies.

All three theories seemed to be contra- icted, but no new alternative was pre- ented. One scientist quipped that the noon must really not exist, since we could ot explain it. With rapid declines in fund- ng after Apollo, most planetary scientists urned away from the problem of lunar rigin in the mid-1970s, and the subject anguished. Quite content to go unex- plained, the moon kept orbiting the earth and adding romance to evening skies.

As a graduate student in the 1960s, I read a good deal of the Soviet work on planetology, only then becoming widely circulated in the West. Schmidt had already pointed out that planets growing from the accumulation of small planetesimals would explain the regularities of the solar system, but other Soviet scientists were proposing an interesting extension of this idea: a few impacts by large planetesimals could explain some of the interesting irregularities. For instance, in 1966 Victor Safronov and his colleagues suggested that Uranus, which spins on its side as it orbits, had experienced a single, large impact. These theories tied in with my own interest in the large impact craters on the moon and Mars. In 1974, Donald R. David, my colleague at the Planetary Science Institute in Tucson, and I calculated the rate at which planetesimals would aggregate into larger bodies near the earth's orbit during the 30 million or so years that our planet was growing. While

Two asteroids collide, spraying rock fragments into space—the origin of most meteorites.

our results agreed with the prevailing view that the earth formed mostly from tiny meteoritic or asteroid-sized planetesimals, we wondered about the largest body ever to hit the earth. From the moon's huge impact basins, now filled with ancient lava flows, we could tell that bodies at least ninety miles across had struck the moon 4 billion years ago. Had even larger bodies struck the earth at an earlier time, creating giant craters that have since been obliterated by the earth's active geologic processes? We concluded from our work that a few planetesimals could have grown quite large before being swept up by the earth. The largest impactor could have exceeded the size of the moon. Our model did not prove this, but merely indicated its plausibility.

The lunar samples also revealed that the moon has more or less the same chemical composition as the earth's mantle, the thick, rocky layer surrounding the iron core. The composition of the mantle is estimated from seismic studies and analyses of rocks brought up by deep-seated volcanism. In addition, the similarity in the oxygen isotope ratios, already mentioned, strongly suggested that the moon formed from material near the earth's orbit—perhaps even from terrestrial material itself. Unlike rocks on earth, however, the lunar material was utterly devoid of water and severely depleted in volatile elements (elements that are driven off by extreme heating). This indicated that whatever the moon's origin, its material had once been heated to high temperatures by some violent process.

With this evidence in mind, we proposed a new theory of lunar origin in which a nearly planet-sized body struck the earth with sufficient force to blast enough debris into orbit to form the moon. The collision happened after the earth's iron had settled to its center, and probably after the impactor's own iron core was formed. With the iron concentrated in the two interiors, most of the ejected debris came from the violently heated mantle material. The heat drove off water and other volatile substances, leaving material with the exact composition to account for the iron- and water-deficient moon. Most of the debris fell back to the earth, but a fraction was lofted into orbit and reaggregated into a satellite.

A closely related idea about the origin of the moon, the only other substantial theory developed in the early 1970s, was advanced by A. E. Ringwood, an Australian geochemist. He proposed that many small impacts kept the early earth hot enough to boil off hot silicate gases, creating a cloud of hot dust around the earth, from which the moon aggregated. The only difficulty with this idea was that if such a cloud formed during the natural course of any planet's evolution, why didn't Venus or Mars, two earthlike neighbors, also have large moons? The beauty of our idea was that it explained why only one planet out of eight (or two out of nine, if you count tiny Pluto and its moon, Charon) has a relatively large satellite.

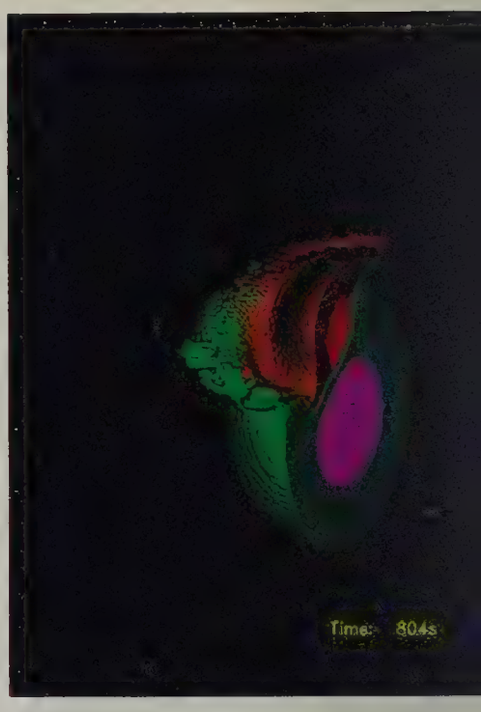
The giant impact was a chance event, a statistical fluke. Whether or not a nascent planet is hit by a planetesimal large enough to form a moon depends on many variables: how big the largest neighboring planetesimal grows before it collides with the planet; if it hits early or late in the planet's growth; and if it hits tangentially, head on, or is deflected by the gravitational pull of a near miss to hit another planet instead.

I first presented our theory at a 1974 conference on satellites at Cornell University. During the question period at the end of my talk, up went the hand of Al Cameron, an expert in planetary evolution, now at the Harvard-Smithsonian Center for Astrophysics. As a relatively young Ph.D., I dreaded a devastating critique that would blow our nice theory to smithereens. Instead, he announced that he and William Ward, an expert in celestial dynamics, had been working on essentially the same idea, but that they had reached their conclusions from an entirely different starting point. They were wondering how big a body needed to be to deliver the total angular momentum of the earth–moon system in one big impact. They concluded that the impacting body was about half the diameter of the earth—or as big as Mars!

At first, the giant impact theory re-

In the first frame of this computer simulation, a Mars-sized impactor makes contact with the earth at about 26,000 miles per hour. Both bodies are cut in half to show the motion of their heavy iron cores, which merge as the collision progresses. Only material from the outer mantles is blasted into orbit around the earth. In the final frame half an hour later, the collision is over. The earth will recover its shape over the next hour, and the cloud of hot debris circling the planet will begin to coalesce into the moon.

Jay Melosh and Marlan Kipp/Sandia National Laboratories

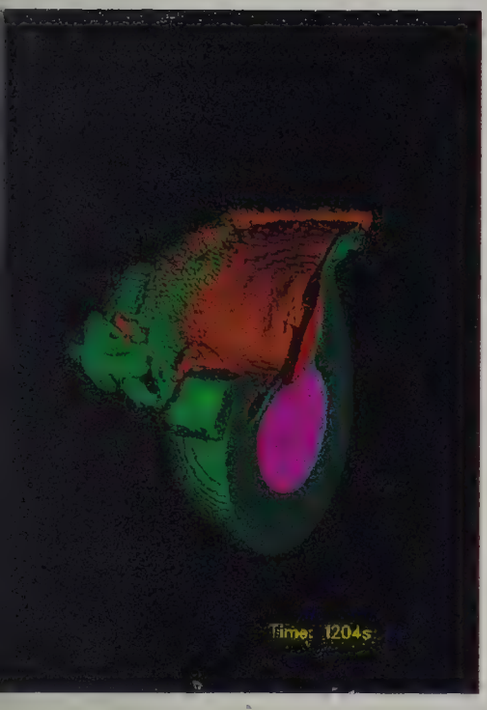


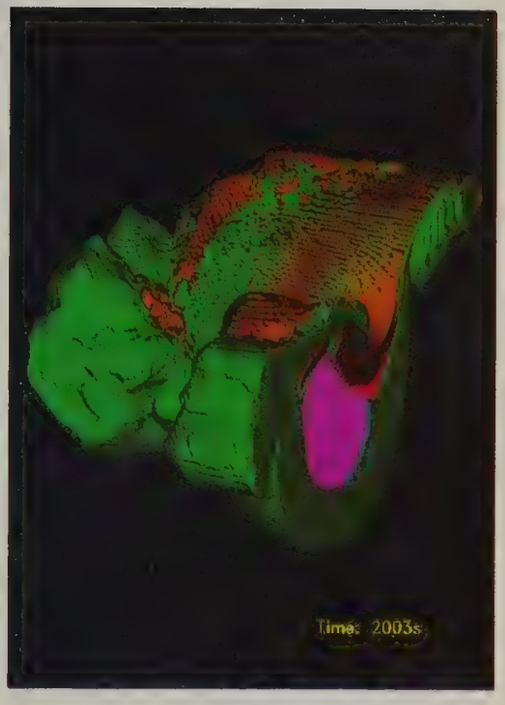
ceived little attention, and when it did, it was often criticized as being ad hoc; we had conjured up our impactor out of the blue in order to explain the moon. Besides, the theory was seen as too catastrophic by the critics, who thought that other, more evolutionary theories should be pursued before such an unlikely and extreme event was considered. But the chance nature of the impact was a strong point in favor of our theory. Although the process of planet formation was more or less orderly and gradual, occasional big impacts may have superimposed some variety on an otherwise dull solar system. Evidence of chaos during the formation of the planets is everywhere: Mercury, which is little more than an iron core with a thin rind of rock, may have experienced an impact large enough to blast away most of its mantle; Venus, which spins slowly backward, may have been struck a glancing blow; both the earth and Pluto have an unusually large moon for their size; Uranus, already mentioned, spins on its side; and Neptune, which seems to have a disturbed satellite system, may have had a close encounter with a large body.

The resistance to the catastrophic nature of our theory was interesting because of its sociological roots. First, all of science has been affected by the principle of uniformitarianism promoted by James Hutton and Charles Lyell: that the earth's complex geology was created by the same processes that are changing the planet today, acting over millions of years. Similarly, Charles Darwin's theory of evolution proposed that life could undergo immense transformations—given enough time. Those ideas, which saw nature as the result of cumulative, gradual change, triumphed over the older, catastrophist theories, which supposed mountains and species were created by a few sudden and dramatic events. The idea that the moon was created in one big spectacular splash, instead of a long series of modest events, had a bad ring to it because it harkened back to the era of catastrophist ideas. Furthermore, planetary scientists had been embarrassed by the controversy over the books of Immanuel Velikovsky, a Russian-born physician. In *Worlds in Collision,* published in 1950, Velikovsky postulated that major collisions and near misses between the planets had occurred in the last few thousand years and could explain ancient legends, such as the Great Flood, the parting of the Red Sea, and Joshua's causing the sun to stand still (the earth briefly stopped turning in one of Velikovsky's near misses). Astronomers could prove that the solar system had not been so chaotic in the last few thousand years, bu in spite of hundreds of lectures arguin against such catastrophism, Velikovsky books became best sellers and the miscon ceptions resulting from his pseudoscienc spread. Our new theory, which attribute the creation of a major feature of the sola system to a giant catastrophe, was there fore not welcome.

Because of this history, and because o the normal inertia of new scientific idea the giant impact theory languished. Wit the decline of funding for lunar explora tion, and with little research being done o the origin of the moon, we were uncertai about how our idea would fare under in tense scientific scrutiny if lunar origi ever became a hot topic.

In 1984, I was asked to help convene conference on the origin of the moo which meant the problem of lunar origi was about to be revitalized. Twelve year after the last Apollo mission to the moo with no widely accepted theory of luna origin in sight, we felt the time was right t encourage scientists to review the larg body of published data and see if an consensus could be reached on where th moon came from. When I met with th other conference organizers in the sum mer of 1984 to review papers submitted t the conference, I was thrilled to find tha





nany leading researchers were con-entrating on the giant impact theory.

At the conference, to counter the criti-ism that the giant impact was an ad hoc dea and to reduce any bias against cata-trophic impacts, I gave a talk titled "Sto-hastic Is Not the Same as Ad Hoc." I tressed that occasional catastrophic mpacts should now be considered as an ntegral part of planet formation and that ve needed to study such impacts to see if neir consequences could explain what we ee in nature. Other researchers gave nore detailed chemical and physical mod-ls indicating that a large impact could ndeed have been sufficient to have blown ff debris with the right composition to orm the moon. After the conference, sev-ral journals reported that the giant im-act theory had emerged as the dominant xplanation of the moon's origin. The the-ry received good marks, too, in various apers published in a conference sum-nary volume by the Lunar and Planetary nstitute in Houston, although some cau-oned against a "bandwagon" effect that vas making the theory too popular.

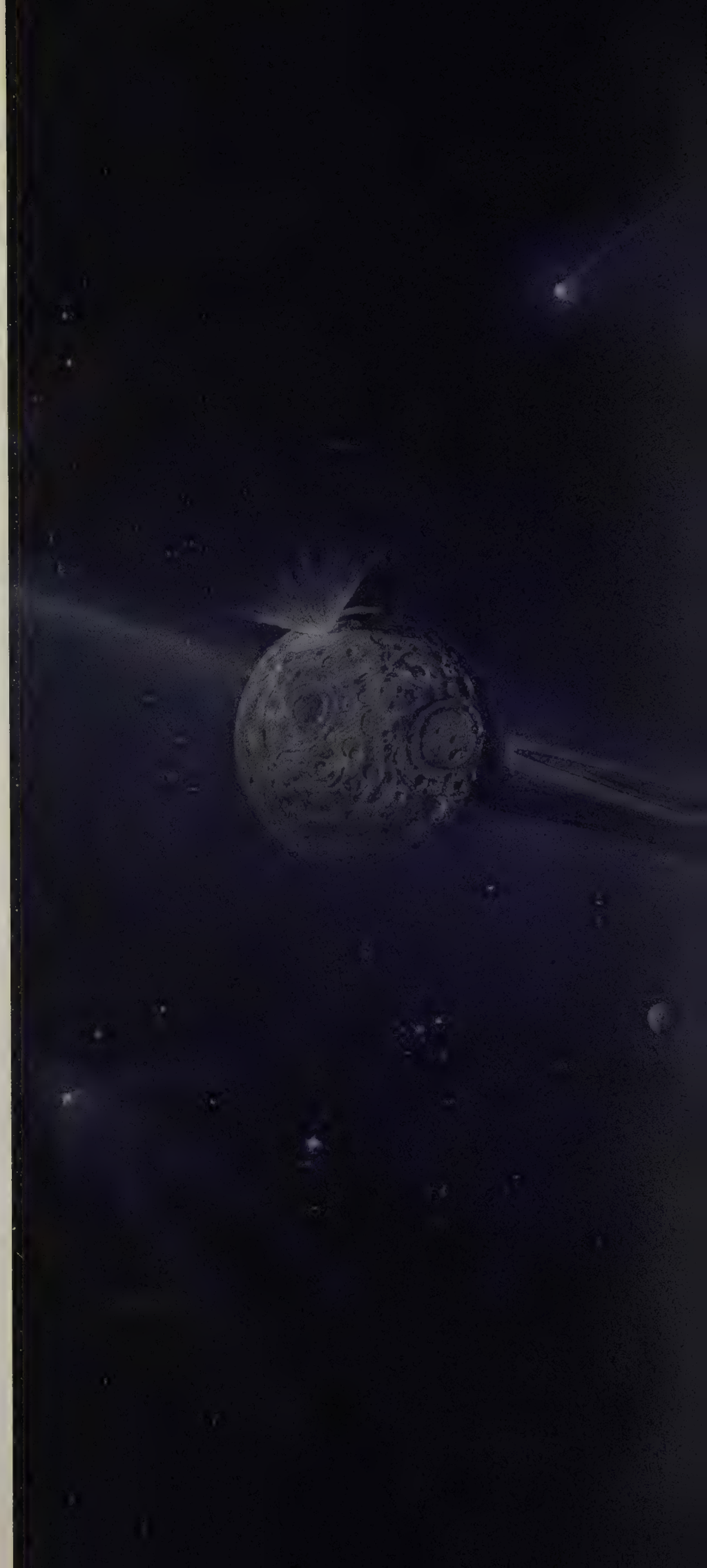
A theory's worth, however, cannot be stablished by winning some sort of popu-arity contest. It has merit only if it en-ourages some useful work, and if it has a hance of being tested against observations in nature. On the first score, our theory proved a success. After the conference, it inspired some extraordinary computer models of hypothetical collisions between two planet-sized bodies. Two independent teams—one led by Al Cameron and Los Alamos physicist Willie Benz, and the other by Jay Melosh, of the University of Arizona, and Marlan Kipp, a Sandia Labs physicist—worked with supercomputers and classified military computer programs (originally written to simulate the violence of nuclear explosions).

At typical orbital velocities, the impactor would have collided with the earth at roughly 26,000 miles per hour. At this speed, the Mars-sized impactor would have taken about ten minutes to move its own diameter, so the collision would have unfolded as if in slow motion.

According to the computer, the impact sprayed hot silicate gases almost as bright as the surface of the sun. At the high speed of collision, each ounce of the Mars-sized body released energy equivalent to that of a pound of TNT. Much of proto-Earth's mantle was blasted away, exposing its iron core. The distorted core of the impactor lost so much momentum that it fell back, plowing into the earth to merge with its core. Much of the ejected material also fell back to the earth in the first couple of days, but a few knots of material, much smaller than the moon, may have coalesced in orbit shortly after the collision. In the first days, a dispersed cloud of hot gas formed around the earth. Before the gas could dissipate into space, fine, hot dust condensed out of it as it cooled. During the first week, the dusty debris settled into a thin ring, like Saturn's. According to studies by David Stevenson, a planetologist at the California Institute of Technology, some of the material in the ring may have been molten for a brief time, like a ring of lava. This material began to aggregate into individual moonlets. The largest of these, perhaps one of the initial knots of matter, would have swept up the rest within a relatively short time, perhaps a few thousand years.

George Darwin, an astronomer and son of Charles, was one of the first to realize that the tidal effects between the earth and the moon have caused the satellite to spiral slowly away from us. This recession has been measured. If you could run an imaginary time-lapse movie of the moon's motions backward, you would see that it was initially very close to the earth (an observation that led Darwin to promote the daughter, or fission, theory). This fact is consistent with the giant impact theory, which asserts that the moon formed from

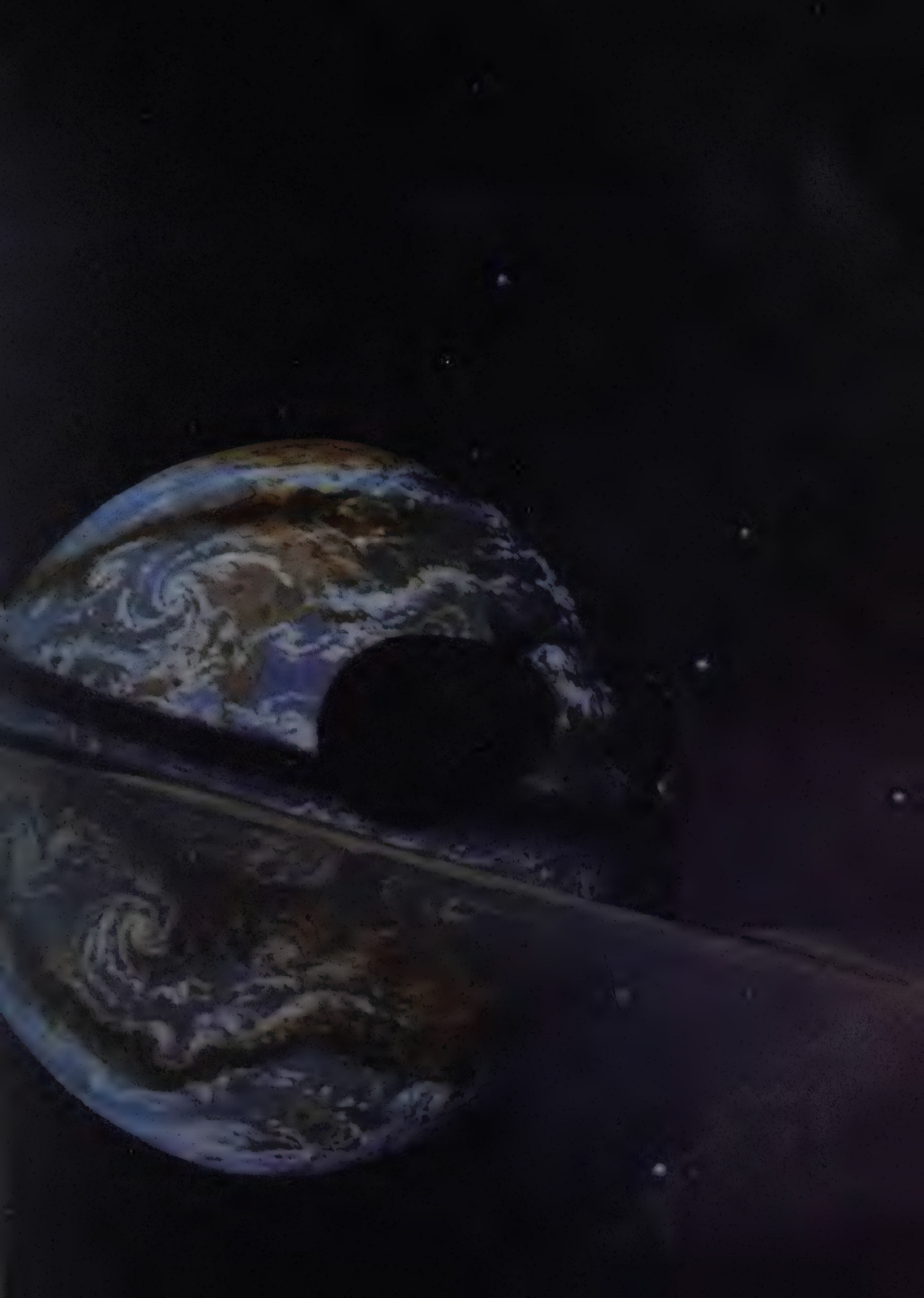
A few thousand years after the giant impact, the new moon orbits close to the earth. Slowly spiraling outward, the moon continues to sweep up debris from the collision, but some material remains in a ring next to the earth.



debris within roughly 15,000 miles of the earth. As it moved outward, the moon swept up any remaining debris in the outer part of the ring. Debris close to the earth gradually dissipated or spiraled inward to crash on the primordial earth, leaving no trace of the ring today. Within a few million years, the moon was already spiraling outward from the earth, toward its present orbit, a distance of 230,000 miles.

In 1988, geochemists pointed out that the computer models suggested a way of testing the giant impact theory. They noted that the shock waves from the impact would have distributed enough energy through the earth's mantle to heat it far beyond its melting point. Previous theories had held that the earth was hot during its formation, but had only reached temperatures sufficient to melt the iron and let it drain through the slushy grains of mantle minerals to the center, where the iron formed the core. The geochemical test of the giant impact theory would examine the mantle's minerals to see if their composition reveals signs of much more severe melting. If the giant impact never took place, the mantle would show only mild melting.

In 1988, Australian researcher A. E. Ringwood and Arizona researcher Michael Drake independently asserted that samples from the mantle do not show signs of the high-temperature melting episode. Drake concluded that this means one of three things: either the giant impact did not occur or the computer models of the impact are not quite right or we don't understand the chemical conditions in the mantle well enough to say whether the melting occurred or not. Many geochemists feel that the chemical evidence remains inadequate to make a conclusive test. The geochemical tests of the theory are in their infancy. The theory has served its purpose, however, in showing what measurements will be valuable in the next few years. The forthcoming geochemical evidence will either strengthen or weaken support for the theory. But for now, the giant impact theory offers the best account of lunar origin, that the moon was born in one of the most violent catastrophes in solar system history. □



One of Idaho's resident boreal owls roosts in a lodgepole pine.
Patricia and Gregory Hayward

Lone Ranger of the Rockies

Why does the diminutive boreal owl lead a restless life of one-night stands?

by Patricia H. Hayward and Gregory D. Hayward

By 6:00 P.M., the February light was fading. I restuffed my backpack after recording data about the subalpine fir, five feet away, where a small brown-and-white boreal owl dozed. The bird didn't even bother to open an eye while I tied a blue flag to the tree so I could relocate it in the summer. Before I finished packing up, a snow squall blew in. The wind's muffled roar and the creaking of trees woke the owl. He looked around anxiously, then shook himself, fluffed his feathers, and went back to sleep, ignoring the snow that fell on his shoulders, melted, and slid over his plumage.

I turned to start the six-mile ski trip back to the cabin to compare notes on the day's owl watching with my husband, Greg. A mile from home, I was skiing by the light of the moon. At the base of a slope covered with ponderosa pine and Douglas fir, I paused to enjoy the quiet and the moonlight, and to rest my aching muscles. In the distance, two coyotes howled a duet, then silence returned. Just as I was about to ski on, the air around me was punctuated by a staccato call that began quietly and crescendoed to a briefly sustained peak—the courtship call of a male boreal owl. I scanned a couple of frequencies on my radio receiver, wondering if the calling bird was one of the owls I had radio tagged. On the third try, beeps came booming in. The Moosejaw male, the same owl I had left an hour and a half earlier and six miles away, was singing on the hill above. I tried a few other frequencies, and more beeps sounded. The Flossie female, an owl that Greg had located earlier in the day three miles to the west, was also up on the hillside. The movement patterns of these two owls typified the behavior of the borealS we studied for more than four years in Chamberlain Basin in Idaho's Frank Church–River of No Return Wilderness. Long-distance commutes are a way of life for this small, forest-dwelling owl. Likewise, travel became a way of life for us as we and our assistants skied and hiked more than 16,000 miles trying to follow the owls as they moved about their home ranges, which averaged 3,700 acres.

The owls we studied inhabit spruce-fir

Robert C. Simpson

forests in the High Rockies, 400 miles south of the species' stronghold in central Canada. Boreal owls breed throughout the northern forests of Alaska, Canada, the Soviet Union, and Scandinavia, where they are the most common forest owl. Until recently, however, ornithologists considered the species a rare visitor to the contiguous United States. Almost by chance, in 1980 we discovered a breeding population of borealls in the wilderness of central Idaho, and by 1985 we knew that these small, secretive owls breed in the high mountains from northern Montana, Idaho, and Washington south to Colorado. Most recently, they have been seen in New Mexico. But even more surprising than the discovery that this species breeds in the United States were our findings of the distances traveled daily by these owls.

Wanderlust appeared to be an integral characteristic of the population we studied. Although a great horned, screech, long-eared, or other forest owl will frequently roost in the same stand of timber—often in the same tree—day after day, we found that a typical Chamberlain Basin boreal almost never roosts in the same tree and frequently sleeps in a tree miles from the one it occupied the previous night.

The owl we called the Boreal Hill male was a good example. His daytime roosts in the winter of 1986 were, on average, more than two miles apart. On March 15, Greg radio tracked this male and found him four miles east of our cabin, sleeping in a large spruce. The next morning I skied from our cabin eager to find several of our radio-tagged owls. (We had used mist nets and mesh cages holding live mice to capture these owls two months earlier while they were courting at their potential nest sites. Radio signals from the small transmitters we had attached, weighing less than two-tenths of an ounce each, do not travel far.) As usual, the radio signal from the male's transmitter was not audible until I reached a high ridge three-quarters of a mile north of home. Twirling the antenna to the west, I tuned in a faint beep. For the next four hours I broke fresh powder as the signal sharpened and I moved

ommon in spruce-fir forests, the red-acked vole, left, is the principal food f Idaho's boreal owls. A vole-bearing nale owl, below, arrives at a nest cavity n an aspen. As sole provider for his nate and brood of unfledged young, a nale may make as many as twelve unting trips per night.

tricia and Gregory Hayward

Boreal nestmates about three and a half weeks old perch on the branches of a lodgepole pine. While boreal owls in the forests of Scandinavia regularly rear five to seven owlets each summer, those in Idaho seldom fledge more than two.
Patricia and Gregory Hayward

higher in the basin toward the bird. My hopes of locating several owls before nightfall faded. Finally, I reached the Boreal Hill male perched low in a subalpine fir, leaning against the trunk, with a dead red-backed vole draped across the branch at his side. This perch was almost seven miles, "as the crow flies," from the previous day's roost and nearly a thousand feet higher in elevation.

Why would these small birds need to travel such long distances and have such large home ranges? Boreal owls rank thirteenth in weight among the seventeen species of North American owls. Weighing from four to six ounces (males are considerably smaller than females), the owls are not much larger than pigeons. Chamberlain Basin borealis, however, occupy areas two to eight times larger than those reported for other small forest owls. The size of their ranges even approaches that of the spotted owl, a species four to five times larger than the boreal. Like other wild animals, boreal owls can't afford to expend energy needlessly. The cost of movements throughout the home range must be offset by greater benefits. Most animals move to locate mates, avoid competition from others of the same species, find shelter from the elements or predators, or find food. Which factors influence Chamberlain boreal owls?

Solitary birds, boreal owls associate with one another only to mate. However, they do not defend territories or actively avoid one another. Their home ranges may overlap extensively; we found males roosting less than one hundred yards apart. To reproduce, a male locates a suitable nest cavity, where he sings his courtship call in the hope of attracting a female. The male confines his courtship calling to a small area around the potential nest cavity and limits any defensive action against intruding males to this same space. In the deep silence of a winter night, the boreal's song can travel miles, and the female must track it to its source. In most years, she doesn't have far to look because several males will most likely call within her home range. Courtship and territorial activities, then, account for little of the boreal owl's day-to-day movements.

If borealis aren't seeking companionship, patrolling territorial boundaries to exclude intruders, or wandering the countryside in search of love, can the search either for shelter or for food explain the large home ranges used by these owls? Shelter from the elements, at least in winter, apparently is not the reason for the distances traveled because boreal owls, which occupy coniferous forests throughout the far north, are superbly adapted for the cold. We often found owls roosting in the open, unprotected from wind or falling snow, even during storms. A perch next to the bole of a conifer appeared to provide sufficient protection. So a search for shelter cannot explain the owls' extraordinary movement patterns.

Although not definitive, several lines of evidence suggested to us that boreal owls at Chamberlain need such large home ranges to obtain sufficient food. The lives of many predators are controlled by the availability of their prey. During the four years of our study, we trapped small mammals, the major prey of boreal owls, to determine how numerous these animals were in various habitats and how much their numbers fluctuated from year to year.

If prey influences the owls' movements, we reasoned, the owls should stretch the boundaries of their home ranges in lean years. Results of our mammal trapping indicated large populations in 1984 and 1987, smaller populations in 1985, and extremely low numbers in 1986. We therefore expected to find relatively little movement and small home ranges in 1984 and 1987, and the opposite situation in 1985 and 1986. Summer movements and home range sizes did increase substantially in 1986. Winter home ranges and movements, on the other hand, were surprisingly constant. At first this seemed inexplicable, but after pondering our data, we began to piece together an explanation.

From the beginning of our study, the scarcity of small mammals, even in "good" years, surprised us. Prey populations at Chamberlain were smaller than those reported in other northern forests. Likewise, the number of young raised by Chamberlain boreal owls contrasted

sharply with clutch sizes reported at higher latitudes. In Scandinavia, boreal owls fail to breed during small-mammal population crashes, but in good years, pairs commonly fledge five to nine owlets. At Chamberlain, one-third to one-half of the nests failed completely, the largest clutch contained only four eggs, and only one nest in four years managed that many. Two or three eggs were the norm, and two young seemed about the maximum Chamberlain owls were capable of fledging.

Chamberlain borealis are relatively unproductive under any conditions and appear to be barely able to sustain their numbers. Sparsely distributed prey forces the owls to search long and hard for their meals. Even in good prey years, the owls must travel widely if they are to eventually put on weight and breed successfully.

In the wild, breeding occurs only if animals obtain the energy to survive. Studies of tawny owls in England have shown that the level of the female's fat reserves before breeding is the primary factor determining the number of healthy young a pair raise in a given year. In boreal owls, as in most owl species, the male does all the hunting for his mate and young from the onset of incubation to near fledging. Not every night, however, is perfect for hunting. During rain, mice and voles stay tucked away in burrows and nests. On such nights the male may be unable to provide enough food for his mate. If her body fat reserves are high, she can sit such nights out, keeping her eggs and young warm. If her fat stores are dwindling, however, she may be forced to leave the nest to hunt on her own, exposing the eggs and young to cold. (Exposure to predators, however, is not a major factor. The main nocturnal predator, the pine marten, may attack even when the female is present.) Thus, any extra fat that a female can acquire prior to nesting helps insure nestling survival. Because Chamberlain boreal owls must range far to find prey even in good years, the size of their home ranges remains relatively constant. Instead, nest success seems to vary directly with the availability of prey.

We did find, however, that the owls

In summer, boreals choose cool roosting spots, such as the shady boughs of an Engelmann spruce. Boreals are solitary; the male and female of a pair may roost miles apart and rendezvous only at the nest site.
Art Wolfe

traveled farther in winter than in summer. In the high mountain areas inhabited by boreal owls, three to six feet of snow blanket the forest for six to eight months of the year. Most prey remain burrowed beneath the snow, taking advantage of the thick insulation to conserve energy and to protect themselves from predators. Tiny tracks, however, attest to the comings and goings of some individuals on the surface. Deep plunge holes encircled by delicate wing tracings indicate where others succumbed to the owls' acute hearing and sharp talons when they burrowed too close to the snow's surface. During this harsh season, the owls have to work harder to find meals. The distance between roosts used on consecutive days, an index of an owl's daily movements, was on the average 66 percent longer in winter than in summer, and winter home ranges were 25 percent larger than summer home ranges. For males, the latter generally encompassed 2,100 acres or more.

In summer, male owls that are feeding families find easy pickings at high elevations in the old-growth spruce-fir forests. Here, red-backed voles, which are one-third to one-half of the boreal owl's diet, are two to ten times more numerous than at lower elevations. While the voles are protected by six feet of snow in winter, in summer they are vulnerable, despite their habit of hiding beneath rotting logs. Even male boreals that nest at lower elevations find long trips to these high-elevation spruce forests rewarding. In fact, males roosted and, we believe, foraged an average of one and a half miles from their nests—a sharp contrast to the behavior of most owl species.

Why don't the owls simply nest at high elevations, where the food is located? Given a chance, most owls probably would. But for nesting they need large tree cavities that are rare in spruce-fir forest, even in the virgin timber of the wilderness. In four and a half years we saw only two usable cavities in subalpine fir and Engelmann spruce. Ponderosa pines, on the other hand, are "hotel trees" that may contain up to ten good holes for nesting. Woodpecker-excavated holes in aspens are also used by boreals. At Chamberlain Basin, both aspens and ponderosa pines tend to grow at low elevations. Thus, Chamberlain boreal owls commute to exploit the resources at both elevations, and their small clutches reflect the cost of this active life style.

The activity of unmated owls further testifies to the role played by prey and cavity distribution in the owls' movements. One unmated male, the Three-Blaze owl, named for the trail running through the middle of his summer home range, had the smallest home range observed. With an abundance of voles underfoot and no need to travel to a nest, he sometimes moved as little as twenty-five yards between roosts. Although he never used the same tree on consecutive days, we found up to twelve pellets of regurgitated hair and bones, some more than a year old, under certain trees. Because boreal owls regurgitate only one to two pellets a day, such a large number under these trees indicated that they were frequently used favorites. During an entire summer, he hunted over an area of only 390 acres. When prey is abundant, an unmated owl has little need or inclination to move long distances. Several mated male and female owls that moved to higher, prey-rich elevations after their nesting attempts for the year had failed also immediately confined their activities to small areas.

In May 1988, after tracking Chamberlain boreal owls for four and a half years, we piled our gear into a single-engine plane and said goodbye to the basin. The plane roared down the dirt strip, then silence settled over us as we lifted off the ground. All the streams, valleys, and ridges we had come to know so intimately fled away below, as did the owls that had taught us so much: the Moosejaw male, the Flossie female, the Three-Blaze and Boreal Hill males, and many others. Less than a decade ago, no one knew that boreal owls resided and bred in the contiguous United States. Since then we've answered many questions about their habits and habitat needs. Now we need to look for new teachers to help us answer our new questions about the future of the Rocky Mountain boreals. □

A salute to one unpretentious kni

Under a hot Southern sun, the 150-day miracle begins anew. A sprout struggles up, grows strong, shows a few brash buds, then a bloom or two, and at long last, the soft white puffs we recognize as cotton.

All the while, the plants are nurtured, worried over by the early-rising people for whom cotton is a way of life. The growers themselves, or people like Texas entomologist B. Bruce Snider, who scouts the plants for the boll weevils that can destroy them.

B. Bruce Snider

Or there, up in the sky, daredevil cropdusting pilots like Roy Lee Morrow and Robert Allen Rhodes. Tough way to make a living!

(It is here, in the land of cotton, that our Lands' End Mesh Knit Shirt is born.)

Harvesting time comes, and big lumbering "strippers" pick the fields clean, leaving huge chunks of cotton —sometimes 20,000 pounds worth— awaiting the trip to the gin.

At the gin, the cotton fibers part company with their seeds (which become the oil you sprinkle on your salad, or the feed for your livestock). The fibers are graded, then compacted into bales and shipped off to the mills.

Roy Lee Morrow and Robert Allen Rhodes

(Only the better grades of long-staple cotton fibers qualify for the Lands' End Mesh Knit Shirt. And it takes over half a pound of raw cotton to make each one.)

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Journey into a Silent World

by Simon J. Carmel

Is the sign language of deaf people an authentic form of human language among the thousand spoken languages of the world? Or is it merely gestures and pantomime without grammar? How do deaf people acquire a written or sign language without hearing a spoken language? Is deafness a medical or pathological view, or a cultural and social view? And why did deaf students suddenly revolt against the appointment of a new university president at Gallaudet University in Washington, D. C., last year?

In his latest book, *Seeing Voices: A Journey into the World of the Deaf,* Oliver Sacks admits that three years ago he knew nothing about the enriched realm of deaf adults and children, their world views or their visual language. When Sacks started to read books on the deaf, he was so enraptured that he began a journey into their silent world. He began to learn the history of deaf people and their completely visual language, "Sign," a language different in mode from his own. (Sign refers to American Sign Language [ASL], as well as to all indigenous signed languages, such as French Sign, Chinese Sign, and so on.) Sacks's journey took him to deaf people and their families; to schools for the deaf; to the unique Gallaudet University of the deaf; to Martha's Vineyard, where at one time everybody (the hearing as well as the deaf) spoke Sign; to towns like Fremont, California, and Rochester, New York, where there are special social areas for the deaf community; and to the researchers on Sign. He was forced to look at language, at the nature of talking and teaching, at child development, the development and functioning of the nervous system, and the formation of communities, worlds, and cultures in a way that was wholly new to him. After his journey, he was left wit mixed feelings. For instance, Sacks wa appalled to learn that many deaf peop never acquire good language or thinkin He learned that deafness is not only biological phenomenon but also a cultur one. And he found that many deaf peop have acquired language of an entirely di ferent kind that serves as the medium of community with a rich culture. Sacks wa aware of the "medical" status of deaf pe ple, but he learned that they are also a "ethnic" group with a distinct languag sensibility, and culture.

The book is divided into three se ments. The first was written in 1985 ar

SEEING VOICES: A JOURNEY INTO TH WORLD OF THE DEAF, by Oliver Sack *University of California Press, $15.9 171 pp., illus.*

1986 when Sacks was asked to review book on the history of deaf people, Harla Lane's *When the Mind Hears.* The secon part was written last, and Sacks places at the heart of the book because it is base on his most personal view of the subjec The book's third part was stimulated b the revolt of the students at Gallaud University in March 1988 and was fir published in the *New York Review Books* on June 2, 1988. However, it w revised and enlarged for this book. Sac emphasizes that, although he is a profe sor of neurology at Albert Einstein Co lege of Medicine in New York, he is a outsider, with no special knowledge or e pertise in the field of deafness: "I am n deaf, I do not sign, I am not an interpret or teacher, I am not an expert on chi development, and I am neither a historia nor a linguist."

Although Sacks claims that deafness is one of the most desperate of human calamities," the book's first part reveals that earing people are vastly ignorant about eafness. Sacks raised the subject of deafess with many hearing people and usually received the same responses: "Deafess? Don't know any deaf people. Never nought much about it. There's nothing *nteresting* about deafness. . . ." He admits that before he read Harlan Lane's ook, he would have made the very same omments.

In the past three centuries, language-ss deaf people have aroused the curiosity nd compassion of philosophers and educators alike. In the eighteenth century, bbé Sicard, a director of the National nstitution for Deaf-Mutes in Paris, asked,

Vhy is the uneducated deaf person isolated n nature and unable to communicate with ther men? *Why* is he reduced to this state f imbecility? Does his biological constitution differ from ours? Does he not have verything he needs for having sensations, cquiring ideas, and combining them to do verything that we do? Does he not get ensory impressions from objects as we do? . . *Why* then does the deaf person remain tupid while we become intelligent?

In another view, the sixteenth-century talian physician Girolamo Cardan proosed that "it is possible to place a deafnute in a position to hear by reading, and o speak by writing . . . . Written characers and ideas may be connected without ne intervention of actual sounds." The otion that understanding ideas does not epend upon the hearing of words was evolutionary in the sixteenth century.

Abbé de l'Epée, the founder of a rench school for the deaf, changed the leas and theories of philosophers by using ne indigenous sign language of the deaf.

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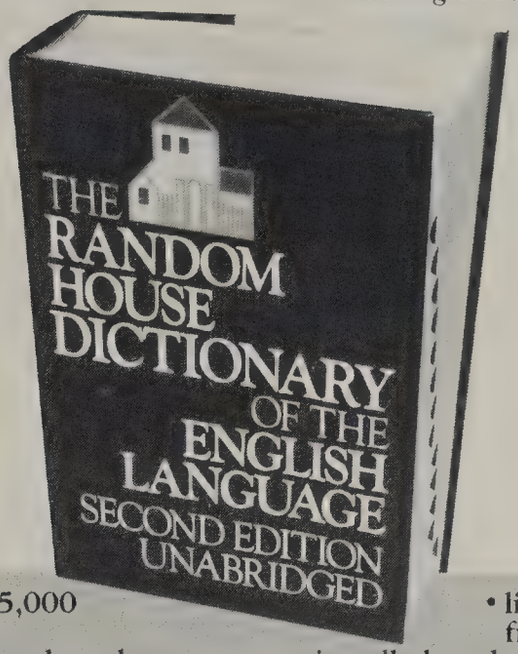

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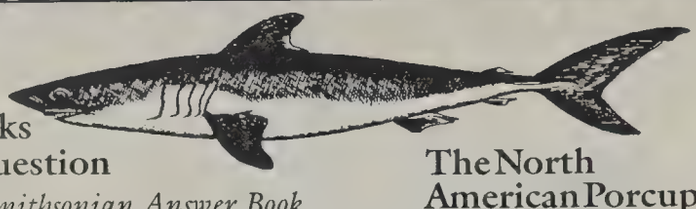

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He could not bear to think of the souls o deaf people living and dying unheeded The abbé acquired their language an then taught them to read, opening th world of learning and culture to them. H founded his school in 1755 and trained hundred teachers for the deaf who, i turn, established twenty-one schools fo the deaf in France and the rest of Europe His school became the National Institu tion for Deaf-Mutes in Paris. Many cele brated philosophers and other public fig ures came to observe de l'Epée's an Sicard's class demonstrations and sa that deaf people were no longer the ou casts of human society.

This period was a kind of golden age i deaf history because with the rapid estab lishment of deaf schools, usually manne by deaf teachers, deaf people emerge from neglect and obscurity and began t appear in positions of eminence an responsibility—as writers, engineers, ph losophers, and intellectuals. In 1816, Lau rent Clerc, a deaf student of Abbé Sicar was brought to the United States b Thomas Gallaudet to assist in establishin the American Asylum for the Deaf i Hartford, Connecticut. Deaf literacy an deaf education increased in the Unite States, as it had in France and throughou other parts of the world. By 1869, 41 pe cent of the teachers of the deaf in the U. were themselves deaf.

In 1864 Congress passed a law au thorizing the Columbia Institute for th Deaf and the Blind in Washington, D. C to become a national deaf-mute colleg the world's first institution of higher learn ing specifically for the deaf. Its first pri cipal was Edward Gallaudet, the son Thomas Gallaudet. Columbia Institu was later rechristened Gallaudet Unive sity; it is still the only liberal arts colleg for deaf students in the world.

Most unfortunately, by 1870 the philo ophy of oralism started to suppress the us of Sign by and for the deaf. And for th past century, teachers and parents of dea children have felt that the goal of dea education should be teaching deaf chi dren how to speak. Edward Gallaudet wa an open-minded man, who in the la 1860s visited deaf schools in fourteen E ropean countries. He found that the m jority used both sign language and speec and that these schools obtained superi results. Gallaudet felt that speech skil could not be the basis of primary instru tion—this had to be achieved early b Sign. In contrast, the "radical" reforme wanted to overthrow the "old-fashioned sign language schools and introduce "pr gressive" oralist schools. At the infamou International Congress of Educators

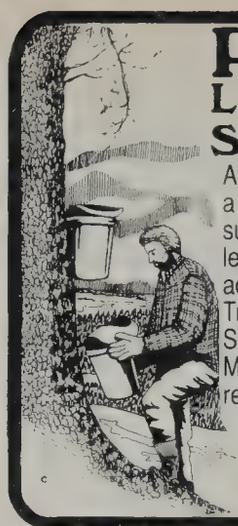
ıe Deaf held in Milan, Italy, in 1880—here deaf teachers were excluded from ıe vote—oralism won the day and the use f Sign in schools was "officially" out-ıwed. Deaf students were forbidden to se their own "natural" sign language.

One of the most salient consequences of ıe Milan conference was that hearing eachers, not deaf teachers, now had to each deaf students. In 1850, approxiıately 50 percent of teachers for the deaf ere themselves deaf. That number fell to 5 percent by the turn of the century and) 12 percent by 1960. More and more, nglish became the language of instruc-on for deaf students, taught by hearing eachers, among whom few knew any sign ınguage at all.

Sacks discovered that oralism and the ıppression of Sign have resulted in a dra-ıatic deterioration in the educational chievement of deaf children and in the teracy of deaf people generally. Congeniılly deaf students suffer from "informa-on deprivation." The content of deaf ducation is poor or insufficient compared) that of hearing children because hear-ıg teachers spend so much time teaching eaf children speech that there is little me for transmitting information, cul-ıre, complex skills, or anything else. Dur-ıg the 1960s historians and psychologists, s well as parents and teachers of deaf hildren, started asking, "What has hap-ened?"

A century after the Milan conference, eaf people are still largely deprived of ıeir own, indigenous sign language. acks points out that profoundly deaf peole show no native tendency whatever to peak. Speaking is a labor of years. In ontrast, they show an immediate and owerful tendency to Sign, which as a isual language is completely accessible to ıem. This is most apparent in the deaf hildren of deaf parents using Sign, who ıake their first signs when they are about x months old and have considerable fluıcy by the age of fifteen months. Sacks ıphasizes that language must be introuced and acquired as early as possible; in ıe case of profoundly deaf children, only y Sign. Therefore, deafness must be di-gnosed as early as possible, and the chilren must be exposed to fluent signers—ıeir parents or teachers. Once signing is arned, deaf individuals have a free flow f information and can acquire reading nd writing, and perhaps speech. There is o evidence that signing inhibits the acuisition of speech.

In the second part of his book, Sacks peaks of isolated deaf people who failed) acquire any language whatever. In the bsence of any real language or communi-



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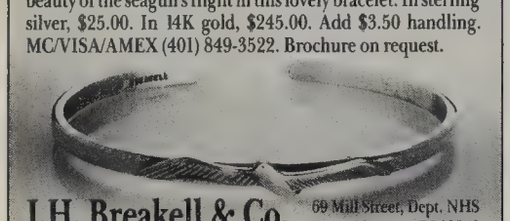
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cation, do these individuals lack intellectual abilities and emotional and social development? Sacks wonders in what ways hearing people have become complete human beings. He raises several questions: "Is our humanity, so called, partly dependent on language? What happens to us if we fail to acquire any language? Does language develop spontaneously and naturally, or does it require contact with other human beings?" Sacks explores different issues focusing on human beings deprived of language, including those suffering from aphasia, which has been a central preoccupation of neurologists since the 1860s.

There is a striking autobiographical sketch by the early nineteenth century French deaf teacher Jean Massieu. Until the age of fourteen, when he became a pupil of Abbé Sicard, he was languageless; later he became fluent in both Sign and written French. Massieu wrote about what his preeducation mind was like: "I saw cattle, horses, donkeys, pigs, dogs, cats, vegetables, houses, fields, grapevines, and after seeing all these things remembered them well." He also had a sense of numbers, even though he did not have names for them. He explained, "Before my education I did not know how to count; my fingers had taught me. I did not know numbers; I counted on my fingers, and when the count went beyond ten I made notches on a stick." When he entered the school for the deaf in Paris, Massieu developed a tremendous, violent hunger for names, just as Helen Keller did when she first understood what "water" stood for and then desired to know the names of all objects surrounding her.

No scientific or linguistic attention was given to Sign until the 1960s when William Stokoe came to Gallaudet University to teach English to deaf students. At that time sign language was seen not as a proper language but as a kind of broken English or pantomime of gestural symbols. In 1960 Stokoe published *Sign Language Structure,* and in 1965, *A Dictionary of American Sign Language* with his deaf research colleagues Dorothy Casterline and Carl Croneberg. Stokoe was convinced that signs were not pictures but complex abstract symbols with a complex inner structure. His book was a double revolution: a scientific one calling attention to the system of sign language and its cognitive and neural levels, and a cultural and political one that helped deaf and hearing people become aware of sign language as a true communal language within the deaf world. Later, scientists at the Salk Institute in San Diego, California, studied the ways in which a sign is changed to express different meanin through grammar and syntax. The showed that the single most remarkab feature of Sign is its unique linguistic us of space. At every level, Sign has lexica grammatical, syntactic, and spatial sy tems. In 1978, Sign researchers demo strated that very finely detailed diffe ences in a sign movement could di tinguish some nouns from related verbs

Many hearing people had thought th deaf people in different countries had universal sign language that enabled the to communicate with one another witho difficulty. Sacks points out that there a many hundreds of indigenous signed la guages all over the world that ha evolved separately and independent wherever there are groups of deaf peopl Although a universal sign language do not exist, there are "universals in all sig language, universals not of meaning, b of grammatical form." Therefore, a de American can make relatively swift co tact with his or her counterparts in Japa Russia, or Peru. Their understanding w usually be established within minutes, a complished mostly by gesture and mim

In closing his second part, Sacks em phasizes that a language's "character" essentially cultural, for it expresses th way a people think and feel and aspire. the case of Sign, the distinctiveness of th language, its character, is biological well, for it is rooted in gesture, in iconicit in a radical visuality that sets it apart fro any spoken tongue. But it is also, an equally, an expression of personal and cu tural identity. For in the language of people "resides its whole thought domai its tradition, history, religion, and basis life, all its heart and soul."

The third part of the book describes th student revolt at Gallaudet Universit which began on a Wednesday morning March 1988, and the author's analysis the inevitable factors that led to it. In 124 years of existence, Gallaudet Unive sity had never had a deaf president. Th students had been actively campaignin for one ever since the last hearing pre dent had resigned. A presidential searc committee selected the six final cand dates—three hearing and three deaf. Th board finally chose Elisabeth Ann Zinse one of the hearing candidates. The board announcement, in addition to the cha man's comment that "the deaf are not y ready to function in the hearing world caused outrage. On March 8, a thousan students closed the university and bar caded the campus entrance doors. Late the faculty and staff came out in suppo of the students and their demands.

Sacks reflects on an earlier visit

dapted from 1602 Venetian book on the peoples of Africa

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General Categories—First ($1,000) and Second ($500) Prizes in each

- Wildlife
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- A Sequence in Nature
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In addition, a number of Honorable Mentions ($250) will be awarded at the discretion of the judges.

RULES

1. The competition is open to everyone except the employees of the American Museum of Natural History, Nikon, and Kodak, and their kin.

2. You may submit no more than six entries (a sequence is considered a single entry). The pictures must have been taken by you and not previously published.

3. If your entry is selected as a winner, you agree to let NATURAL HISTORY publish, promote, and exhibit the photographs and you agree to lend the original picture to the magazine.

4. All entries *must* be unmounted prints, preferably in double-sized or jumbo version, but no larger than 5 by 7 inches. Do not send original slides or film. Put the category of entry and your name and address on the back of *each* print.

5. Include an official entry form (or a facsimile) completely filled out with your entry.

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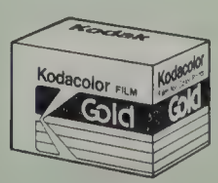

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made to Gallaudet, in 1986–87, an experience that was both astonishing and moving. After attending philosophy and chemistry classes in Sign and observing the wonderful social scene in the student snack bar, with hands flying in all directions, Sacks realized that Sign might be "a complete language—a language equally suitable for making love or speeches, for flirtation or mathematics." These experiences changed his previous "medical" view of deafness to a "cultural" one—deaf people forming a community with its own language and culture. He also sensed an unspoken tension between faculty and administration. There were many teachers who signed, and some were deaf. But only a small number of the faculty members at Gallaudet were deaf in contrast to the numbers during Edward Gallaudet's day.

At the time of the uprising, Sacks was overwhelmed when he gazed around the campus "filled with passionate Sign, with passionate soundless conversation." At that moment he sensed that the students deserved one of their own, that no one not deaf, not signing, could possibly understand them. The students would be cut off from any president who was not one of them. They were tired of hearing the "You can't" syndrome for so many years. They really needed a deaf president who understood the deaf and the need for education, culture, language, and leadership. Sacks witnessed the "transformation" of the communal mind of the Gallaudet deaf community. The deaf students suddenly were no longer passive, scattered, and powerless. The transmission of deaf culture came not only through Sign but through their schools as well. These schools acted as foci for the deaf community, passing down history and culture from one generation to the next. Sacks sees that deaf individuals have their "identity" as a "people" with their own culture, like the Jews or the Welsh. The deaf have had a long struggle to break the old-fashioned concept of "pathologizing" deaf people.

In the past, some doctors tended to see "the deaf merely as having diseased ears and not as whole people adapted to another sensory mode." Deaf people felt this to be an offensive value judgment by hearing people—a way of saying, "We know what is best for you. Let *us* handle things." Deaf people felt they were being dictated to, being told whether or not they could use Sign, being judged as to their capabilities for education and jobs. They were being treated as children.

In contrast, the students at Gallaudet showed a high competence in managing the March revolt. They contacted the

press and television for interviews and issued press releases around the clock. They successfully gained the world's ear. Later, Dr. Zinser, having reexamined her assumptions and views, saw things in a new light and resigned. On Sunday evening, March 13, a new chairman of the board and a new president, both deaf, were appointed.

At the end of the book, the author presents, for his curious readers, a good selected and annotated bibliography. But there is a tiny flaw in Sacks's book—there are too many lengthy (albeit informative) footnotes. And I am somewhat bothered in regard to Sacks's meetings with researchers and other individuals. I don't know if he has a tendency to "patronize" deaf people, but he does mention that he spoke in depth with a number of hearing researchers and experts on deafness. Although he did speak with a few deaf people, he does not mention whether he ever had the same in-depth discussions with any well-known deaf people like community leaders, sociologists, teachers, actors, writers, and so on. There are important deaf people who could be of great help to anyone, including Oliver Sacks, who wishes to understand the history, language, and culture of deaf people. Of course, I am fully aware of Sacks's limited use of sign language, but he could have conversed with deaf people via a TDD (telecommunication device for the deaf) or with help from an interpreter hired for personal interviews. Above all, I must admit that Sacks's book is most informative and stimulating, and I must praise his intense research and crystal-clear understanding of the deaf world. So I strongly recommend that his book be read by those individuals who want a better understanding of the cultural, educational, historical, linguistic, psychological, and sociological discipline of deafness.

I would like to echo, in closing, anthropologist James Spradley's passage about his young deaf niece's problems with identity and language acquisition:

> Deafness is far more than loss of hearing. Deafness is a social and cultural condition. The shared meanings of deafness held by the deaf often contrast with the meanings held by the hearing.

Born deaf, anthropologist Simon J. Carmel is an assistant professor at the National Technical Institute for the Deaf at the Rochester Institute of Technology. He travels around the United States and other countries giving lectures and workshops on deaf folklore and culture. He is the author of International Hand Alphabet Charts *(S. Carmel, 2d edition, 1982).*

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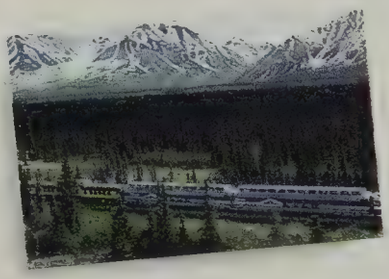

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AT THE AMERICAN MUSEUM

MARGARET MEAD FILM FESTIVAL

This year's Margaret Mead Film Festival, from Monday, December 4, through Thursday, December 7, will present forty-eight anthropological documentaries representing some thirty cultures around the world. Thirty-seven of the films will be U. S. or world première screenings. Filmmakers and anthropologists from eleven countries will discuss their work.

Opening night will feature three films on the theme of pilgrimage. *Dust and Ashes* portrays India's Kumbh Mela Festival, which draws 15 million participants. In *The Lost Army,* an offbeat expedition searches the Egyptian desert for a fabled army said to have disappeared 2,500 years ago. *My Father, My Country* documents Meg Taylor's journey to the highlands of New Guinea in search of her explorer-father's routes and her own roots. On the same evening, four films dealing with the themes of sex, love, and marriage will be shown. *Al Hajji and His Four Wives* focuses on a Moslem household in northern Cameroon. In *Green Tea and Cherry Ripe,* Japanese war brides reflect on their lives in Australia. *My First Time* shows Americans recalling their first sexual experiences, and *The Beacon and the Star* explores the relationship of two middle-aged men in rural England.

Films shown during the rest of the festival treat the themes of continuity and change, trials of the spirit, the world beyond, film and filmmakers, and the search for self. In *Zulay, Facing the 21st Century* an Ecuadorean Indian is introduced to the filmmaking world of Los Angeles, while in *Paul's Story: A Saami in New York* a young Lapp director speaks for himself. *Birthplace Unknown* follows two Korean orphans raised in Holland as they return to their native land. World War II and Vietnam veterans tell their stories in *Navajo Code Talkers* and several other films. *Forbidden City, USA* documents a part of San Francisco's hidden history, a Chinatown nightclub that thrived fifty years ago. Films on Africa feature the orchestral xylophone music of the Chopi of Mozambique, a Baka family in the Central African rain forest, water spirits in Nigeria, and the Mangbetu of northeastern Zaire. Among the other subjects are honey hunters in Nepal, an Italian family circus, the organizing of a Rio slum, and the struggles of Estonian Jews.

Screenings are from 6:30 P.M. to 10:30 P.M. nightly. Admission is $6 per evening ($5 for members). Seating is on a first-come, first-served basis. Tickets go on sale at 5:00 P.M. daily. There are no advance sales. For more information and a full schedule, call (212) 769-5305.

CONCERTS AND LECTURES

Two anthropologists speak at the Museum this month. On Thursday, November 9, Marvin Harris, author of *Cannibals and Kings,* will discuss "Equality and Inequality Between the Sexes Through the Ages" in the Main Auditorium at 7:00 P.M. Admission is free; for more informa-

Sabine Jell-Bahlsen

In Mammy Water: In Search of the Water Spirits of Nigeria, *a water deity gives power to women. This documentary will be shown during the Margaret Mead Film Festival.*

Forbidden City, USA *documents a little-known aspect of San Francisco's past.*

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ion, call (212) 769-5315. On Tuesday, November 21, at 7:30 P.M. in the Main Auditorium, Anna Roosevelt will discuss he culture of Marajoara, an ancient Amazonian civilization whose ruins she nas been excavating. Tickets are $7 for members and $10 for nonmembers. For reservations for this program, call (212) 769-5606.

The Museum will host a pair of special concerts in November. "The African Drum" combines drumming, story, song, and dance in an energetic presentation highlighting the regeneration and evolution of African dance and drumming styles. Several of the master musicians who first brought African drumming to the United States will perform separately and together: Babatunde Olatunji, Chief Bey, and Ladji Camara will be joined by the Drumsong Society/Sabar Ak Ru Afrique. This free program takes place on Friday, November 15, at 7:30 P.M. in the Main Auditorium. For information call (212) 769-5315. On Thursday, November 30, at 7:30 P.M. in the Main Auditorium, living folk-music legend Odetta performs, accompanied by bluesmen John Cephas and Phil Wiggins. Tickets are $12 for members and $15 for nonmembers. For information, call (212) 769-5606.

Native American Celebration

The Leonhardt People Center celebrates Native American culture with free weekend programs in November. On November 4 and 5, Vira and Hortensia Colorado tell healing stories, Dan Charging Hawk discusses growing up Lakota, and Nadema Agard talks on cultural exchange. On November 11 and 12, Abel Silvas recounts a traditional California tale, Bill Cuellar discusses Cherokee and Iroquois art and history, and Jim Murphy demonstrates the art of string figures. On November 18 and 19, the Thunderbird Dancers perform, Ina McNeil discusses Lakota family etiquette, and Leslie Tillett speaks on Native American artists and historians. The People Center will be closed on November 25 and 26. For a schedule of events, call (212) 769-5315.

These events take place at the American Museum of Natural History, located on Central Park West at 79th Street in New York City. For more information about the Museum, call (212) 769-5100.

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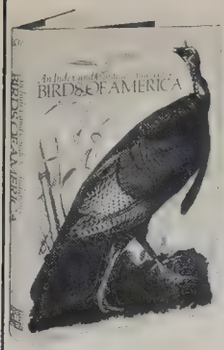

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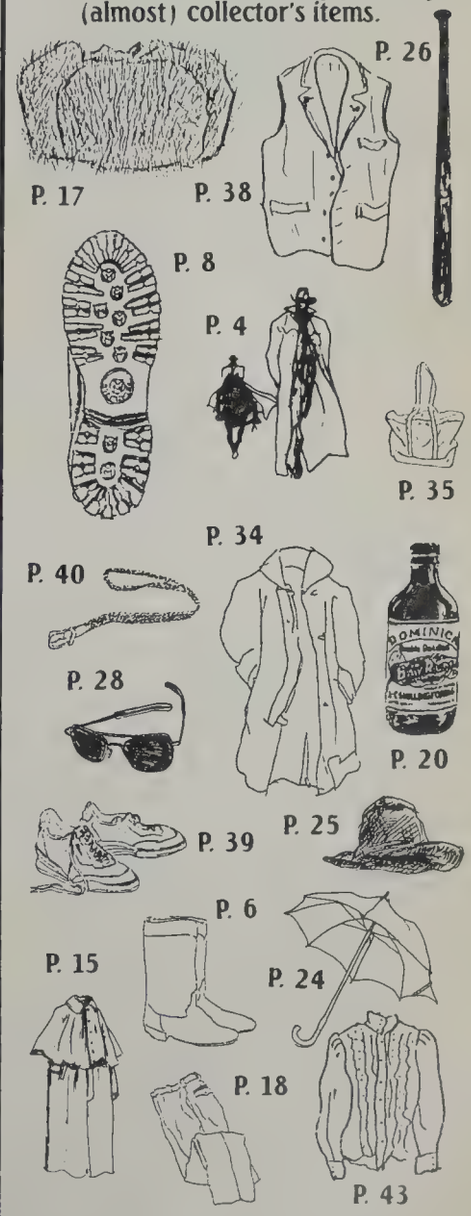

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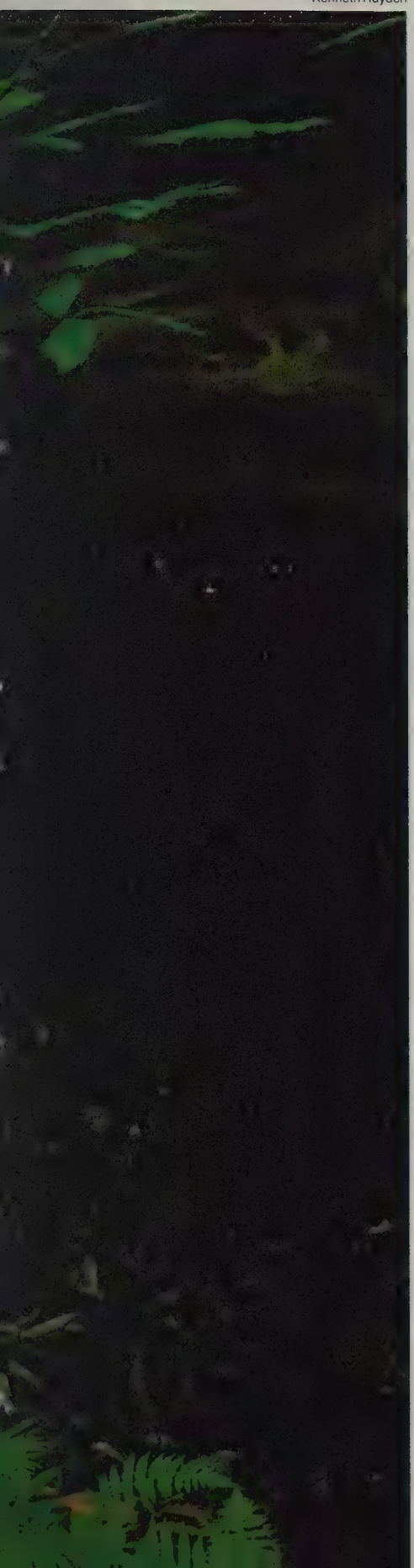
Plaster Creek, Indiana

by Robert H. Mohlenbrock

Kenneth Hayden



Botanist Mike Homoya first saw a seep spring—a spring-fed boggy area in the forest that supports the growth of tall royal and cinnamon ferns—in his native southern Illinois. In 1980, when Mike began work at the Indiana Department of Natural Resources, he was told that seep springs were unknown in that nearby state, but his interest was aroused by a 1982 report that cinnamon ferns were growing five feet tall in a "swamp" on private property in southern Indiana. Accompanied by fellow explorer Tom Post, Mike sought out the spot and found that it was indeed a seep spring, although the area was far from pristine. The two searched further and about a half mile away discovered extensive seep springs along Plaster Creek in Hoosier National Forest.

Recently Mike invited me to see the Plaster Creek seep springs for myself. We parked at the top of a hill, walked across an abandoned field, and hiked through an upland forest of white oaks, red oaks, and a few hickories. We soon found ourselves on top of a narrow sandstone ridge, which juts westward into the canyon carved by Plaster Creek. For most of its length the ridge is less than forty feet wide and drops off precipitously on either side for nearly one hundred feet to the canyon floor.

The major species of tree on the ridge—in some places, the only one—is the rock chestnut oak, so named because its coarsely toothed leaves are reminiscent of those of the American chestnut. Throughout its range in the eastern and central United States, the rock chestnut oak grows on such rocky exposures, tolerating dry conditions thanks to its deeply penetrating roots. Also growing on the ridge are some blackjack oaks, whose leathery, wax-covered leaves conserve moisture, and scarlet oaks, notable for their brilliant autumn foliage. The shrubs beneath the trees reflect the acidic nature of the underlying sandstone. They include mem-

Robert H. Mohlenbrock

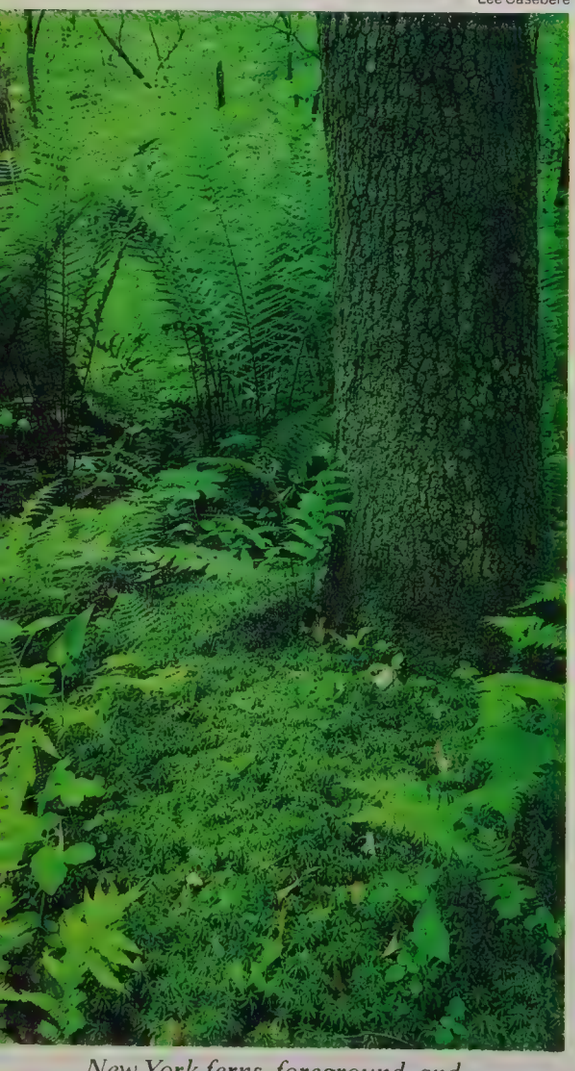
Water seeping from the base of a sandstone cliff, left, supports the growth of New York ferns. Fire pink, above, blooms below the crest of the sandstone ridge.

Joe LeMonnier

bers of the acid-loving heath family—low bush blueberry, farkleberry, deerberry, and black huckleberry—and clumps of poverty oat grass.

The drier southern edge of the ridge has expanses of sandstone where few trees or other flowering plants have been able to gain a foothold. Such sandstone glades, as they are usually called, are common in adjacent southern Illinois (see the September 1988 "This Land" on Bell Smith Springs) but are unusual in southern Indiana. Several kinds of lichens and mosses etch a home on the exposed sandstone. Slowly but surely these plants break down the rock, which together with their decaying bodies, forms a thin soil where other plants may take root.

Lee Casebere



New York ferns, foreground, and cinnamon ferns, background, grow tall in the seep springs habitat.

As the peninsula-like ridge narrows to its western end, it drops off gradually enough so that one can scramble down to the valley floor below. Immediately beneath the crest the habitat becomes less arid, and the rock chestnut oaks are replaced by white and red oaks. Perennial herbs help fill out the understory and include such brightly colored wildflowers as fire pink, purple oxalis, and false woodland dandelion. Toward the base of the slope, where increasing moisture permits greater growth of trees, American beech, tulip poplar, and sugar maple become dominant. Christmas and marginal shield ferns, two handsome woodland ferns that remain green during the winter, grow in large tufts among the moist rocks that have broken away from the cliff.

Nearby, at the foot of the ridge's northwest-facing cliffs, grow the large ferns that signal the presence of seep springs, which are fed by the rain that falls on the ridge and the upland forest. The water works its way down through narrow fissures in the sandstone to an impenetrable layer, then seeps horizontally across the sandstone until it emerges near the bottom of the cliffs and drains into the valley. The seep springs community is a long, narrow band, about five acres in extent, that includes large patches of sphagnum moss, as well as ferns and seed plants. The area is so wet and boglike that walking into it is dangerous.

The royal ferns and cinnamon ferns are the most striking of the seep spring plants because their fronds are as much as five feet long. Smaller but conspicuous for their abundance are New York ferns, marsh ferns, and sensitive ferns. Here and there grows hay-scented fern, with its graceful drooping fronds, as well as lady fern, interrupted fern, and the rare crested shield fern.

Trees such as sweet gum, red maple, green ash, and American elm are common, but none grow to a large size. Windstorms are apt to uproot them, since the soupy substrate provides poor anchorage. Shrubs adapted to soggy, saturated soils are also plentiful: winterberry, Virginia willow, swamp rose, black chokecherry, and buttonbush. Perennial wildflowers add color at different seasons of the year: wild blue iris blooms in the spring, clubspur orchid in early summer, white turtlehead in late summer, and swamp goldenrod in the fall.

The bluff face adjacent to the seep springs is kept very moist by water seepage and the heavy shade provided by the trees. The rocky surface is covered by a dense layer of mosses, through which creep ground pines and partridge berries.

On our way back, Mike and I decided not to retrace our steps up the slope but to follow the base of the north-facing sandstone cliffs. Along the way I saw still more wildflowers, although I then had to clamber up some fairly slippery rocks to get back to the top of the ridge. After I returned home, I realized the entire Plaster Creek area is so untouched that it lacks nonnative plants—no Japanese honeysuckle, woolly mullein, sweet clover, or meadow fescue. With considerable justification, seventy-two acres that include the Plaster Creek seep springs have been proposed as a Research Natural Area, a place whose features are to remain undisturbed.

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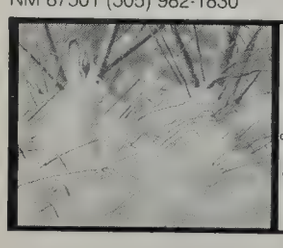

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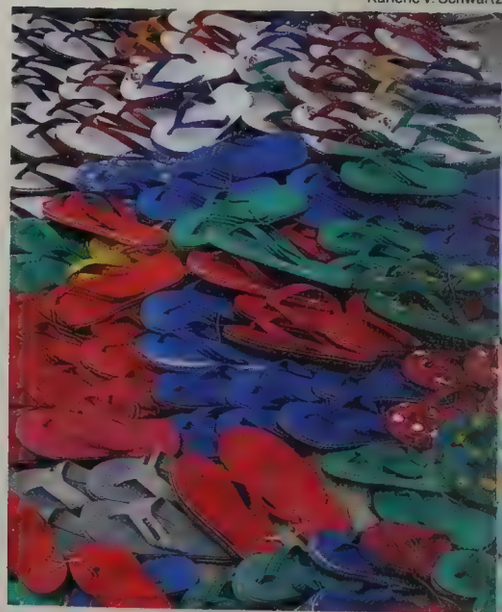

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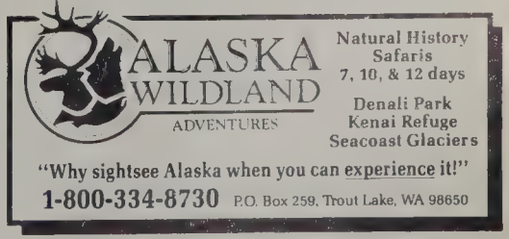

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The Northern Lights Hea

by Thomas D. Nicholson

Earlier this year, on March 12, shimmering curtains, arcs, and bands of iridescent light danced across the nighttime skies of North America from Ontario to Honduras and the Caribbean. Not often seen that far south of the Arctic Circle, the northern lights performed their best celestial show in recent memory, at times filling the sky with brilliant red and green light. Although such a spectacular auroral display may not be repeated soon, we can expect to see more of the northern lights in the next few years; auroras are intimately tied to events 93 million miles away on the surface of the sun, and some scientists are predicting that the new solar cycle will be an exceptionally active one.

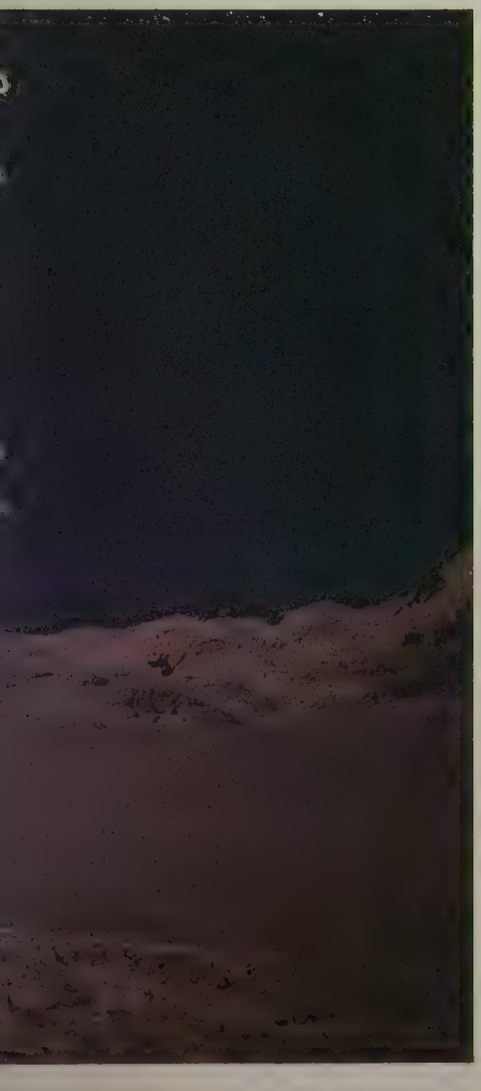
The surface of the sun is continuously emitting matter into space in the form of charged atomic particles, such as electrons and protons. When this so-called solar wind reaches us after a few days, the particles (mostly electrons) are deflected away from the earth by the magnetic field that envelopes the planet. Some, however, are channeled downward toward the earth's atmosphere into a great opening around each magnetic pole to produce the aurora borealis in the Northern Hemisphere and the aurora australis in the

All photographs taken by David C. Fritts on Alaska's Canwell Glacier.

outh

outhern. These magnetic poles are offset rom the geographic poles; the magnetic orth pole, for example, is located in orthern Canada near Ellesmere Island.

Auroral displays result when solar-wind lectrons collide with the atoms and mole-ules of the gases in the thin upper atmo-phere. The electrons transfer their energy the gases, which then release the energy the form of light. (The same principle auses neon tubes to glow when subjected a high-voltage current.) Generally, low-nergy electrons produce reddish-hued uroral patterns at altitudes of 100 miles nd more, while more energetic electrons



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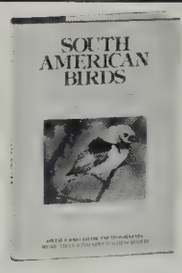

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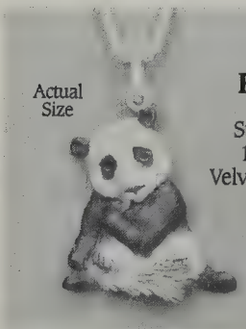

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create greenish displays at altitudes as lo as 50 to 60 miles; in both instances, oxyge atoms are mainly responsible for the ligh although lesser amounts of light are als emitted by nitrogen, the atmosphere most abundant constituent.

The auroras that occur nightly in th skies of the high latitudes, usually at abou 65 degrees north and south, are caused b the normal influx of solar-wind particle but the spectacular southern show las March was initiated by a series of sola flares. Among the most violent ever re corded, these flares ejected a dens stream of charged particles in our genera direction. The strong burst saturated th earth's magnetic field with electrons an protons, producing auroras over a wid area far from the poles (the protons ar largely responsible for extending the aur ral displays beyond the polar locales).

Solar flares are, in turn, related to sun spots, intensely magnetic regions on th sun's turbulent surface that spawn a larg number of outbursts. The solar flares las March erupted from a group of spots larg enough to engulf 150 earths. Sunspot have been increasing in number since las March, and many are typical of a new solar cycle, appearing at higher latitude on the sun and reversed in magnetic polar ity from the spots of the old cycle, whic are still seen near the sun's equator.

The number of sunspots reaches a max imum every eleven years. The cause o such sunspot cycles remains somewhat o a mystery, and without a clear under standing of their cause, predictions of how rapidly the new sunspot cycle will develop how intense it will be, and when it wil reach its peak are all uncertain. Yet be

use sunspot activity tends to be highest uring the first few years of a new cycle, id because the rapid sunspot increase in is one indicates that it will be more ac- ve than those in the past few decades, we ay see more auroral displays in the idlatitudes during the coming years an we have in the past.

Events in the calendar below are given local time unless otherwise indicated.

November 1: The new crescent moon, w in the sky after sunset, is near Antares. aturn and brighter Venus are visible ove and to the left of the moon.

November 2: The Taurid meteor ower is not abundant, with only fifteen so meteors per hour for about a week, it does have the advantage of a dark sky ter midnight.

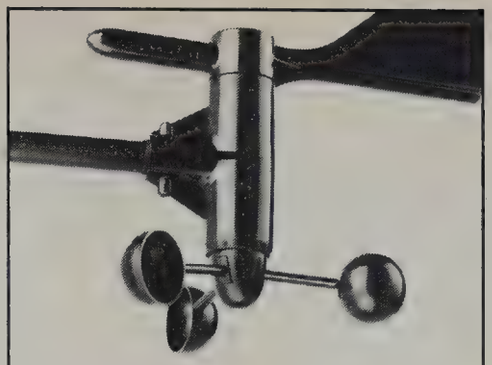
November 3: After passing Saturn at 00 P.M., EST, tonight's moon appears to e planet's left. From 3:00 A.M. to 5:00 M., EST, the moon passes three planets: ranus, Saturn, and Neptune.

November 5–6: While passing through apricornus, the thick crescent moon oes not obscure the constellation's stars. he moon is in the right portion of this kini-shaped constellation on the 5th and its left on the 6th, when first-quarter oon occurs at 9:11 A.M., EST.

November 8: Venus is at greatest east- ly elongation (its maximum distance to e left of the sun). Ordinarily, this is the est position to view an evening planet, ut because Venus' location is so south- ly, it sets early for an elongation.

November 11: The two stars close to the oon are Hamal and Sheratan in Aries.

November 12–14: The moon is at peri-



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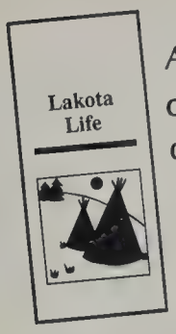

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gee (nearest the earth) at 8:00 A.M. on the 12th and full at 12:51 A.M. on the 13th, EST. The moon is in Taurus on the 13th and above and to the left of the V-shaped Hyades cluster on the 14th.

November 15–17: Venus passes below Saturn from right to left on the 15th and will be lower than, and to the left of, Saturn in our sunset sky. The moon joins brilliant Jupiter in Gemini, switching from its right on the 15th to its left on the 16th. Gemini's Pollux and Castor, the two bright stars to the left of Jupiter, are aligned with the moon on the 17th.

November 18: Unfortunately, a gibbous moon brightens the morning sky when the Leonid meteor shower is at maximum. About fifteen or so meteors per hour may be visible.

November 19: Last-quarter moon, at 11:44 P.M., EST, is in Leo. The Lion's bright star Regulus is below the moon when they rise just before midnight.

November 20–21: A waning crescen moon rides up the eastern sky below Regu lus after midnight. The Lion's stars are t the moon's left.

November 25: The thin morning cre cent moon rises about 4:30 A.M., just belo Virgo's bright star Spica; the moon is als at apogee (farthest from the earth).

November 26: About 6:00 A.M., look fo a thin crescent moon, with ruddy Mars t its left.

November 28: New moon is at 4:4 A.M., EST.

November 30: The crescent moon o the new lunar cycle may be visible tonigh very low in the southwest at dusk. Brigh Saturn is above the moon, and brilliar Venus is some distance to the left.

Editor's Note: The Sky Map in the Octo ber issue shows the evening stars and cor stellations for this month and gives th dates and times for use.

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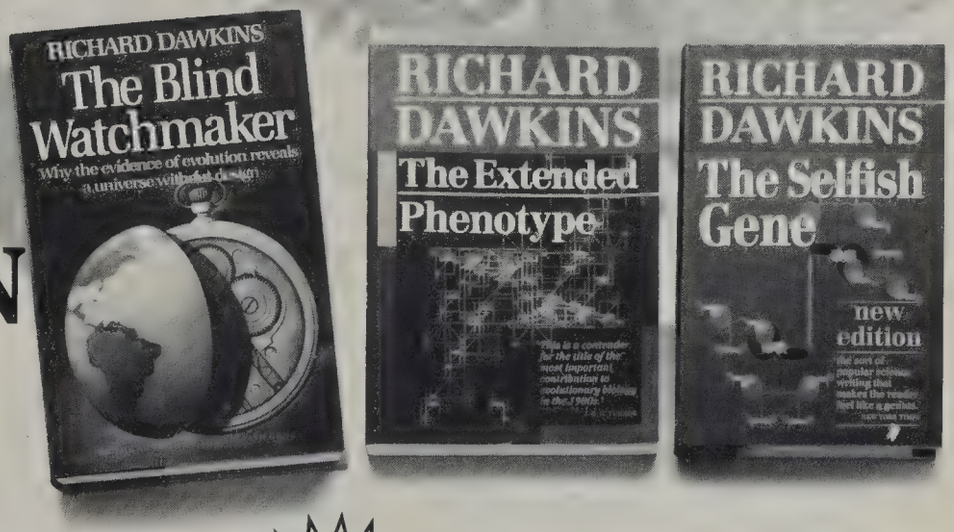

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Natural History 11/89

How to Eat Like an Aztec

Before 1492, the only domesticated animals in Mexico were the turkey, the dog, the Muscovy duck, the bee, and the cochineal insect

by Raymond Sokolov

To taste the food the Aztecs ate before Columbus, it is not necessary to buy a butterfly net or to bone up on Mexican entomology and do historical research in the Nahuatl codices that record local life before Cortés. Many of the now-eccentric ingredients are still routinely available in Mexican markets that also sell imported canned goods from the United States and Western Europe. And you can sample these foods already prepared at a big and cheerful restaurant located in the heart of Mexico City.

In a way, the Fonda Meson de Alonso is a food museum. Only a short way away from the city's main square, the Zocalo, near the location of the old central market of La Merced, this restaurant militantly devotes itself to foodstuffs that predate the arrival of the hated *gachupines* (natives of Spain) in 1519. On the way in, you pass wormlike butterfly larvae harvested from cactus and mounds of grasshoppers. Other, more conventional restaurants in town serve some foods like this; it isn't unusual to encounter *huitlacoche* (the fleshy gray-black corn smut) or cactus paddles (*nopales*) in markets and even in luxury hotels. But as a center of Mexican "roots" food, the Fonda Meson de Alonso is in a class by itself.

Under a ceiling hung with dozens of pastel-colored "chopped paper" cutout banners saying "*felicidades*," the first-time visitor focuses on the ant eggs in green sauce (*escamoles en salsa verde*) and the toasted grasshoppers in guacamole. There are also crunchy patties of mosquito eggs in *mole* and iguana consommé. These dishes look fearsome, but turn out to be a bit of a stunt, since the weird ingredients do not have weird tastes, only interesting textures. The flavor of these dishes comes from their sauces, which may or may not have been added to these foods before 1519 (or even 1979).

And a serious look at the menu confirms one's sense that this raffish bistro is not making any real effort to reproduce Aztec cookery, but only means to incorporate some surviving Aztec ingredients into a general offering of *macho* dishes that include venison meatballs, quail, and allegedly, mountain lion. The methods of cooking often use some process or ingredient of European origin. The quail is cooked in wine.

The most crucial difference between this menu and any selection of food possible before Cortés is also the one that most of us would take as its least dramatic feature. Amid the bugs and worms and game are many dishes made from ordinary barnyard animals. Some of the recipes may be off-putting—calf's foot, bull's testicles. But it is the finding of beef and pork and goat in any form on this menu that brands it irrevocably as post-Hispanic.

The Aztecs had only five domesticated animals, as Sophie Coe reminded us in her survey of their cookery in *Petits Propos Culinaires* (nos. 19–21): the turkey, the Muscovy duck, the dog, the bee, and the cochineal insect. (The situation was not much better in the Andes, where the guinea pig was—and is—a basic meat source, and various camelids, notably the llama, substituted for horses, oxen, and other beasts of burden that were widespread in Europe.)

So before 1492, Mexican cuisine had no dishes with beef, pork, or lamb. There were no dairy products—no milk, no cream, no butter, no cheese. Fried foods were unknown. Then, in 1493 Columbus returned to the New World on his second voyage and brought European livestock with him: horses, dogs, pigs, cattle, chickens, sheep, and goats. He came with seventeen ships and 1,200 men, and in the holds of those ships were, literally, the seeds of colonization. Columbus brought what was needed to start plantations and orchards and kitchen gardens; the wherewithal to grow onions, grapes, fruit, radishes, and sugar cane. The Antilles soon were producing such exotics as lettuce, cauliflower, citrus, figs, and pomegranates. The banana, originally Asian, had been established in the first Spanish colony, the Canary Islands; from there it was brought to the Caribbean in 1516 and flourished.

So did wheat. Alfred W. Crosby in *The Columbian Exchange* catalogs the spread of the Spanish staple, planted wherever the conquistadores established farms. This was official policy, and by 1535 Mexico was exporting wheat to the Antilles.

Even more spectacular was the swift adaptation of the pig to the New World. Reading Crosby's several pages on the subject, one is tempted to say that the New World was conquered by swine just as much as it was by the Spaniards. There were literally thousands of pigs on this side of the Atlantic by 1550.

In many of the places where hog and hidalgo settled, they were free to adapt the cuisine of the mother country to local conditions without any, or with only trivial, contact with indigenous foodways. Whatever Arawak or Taino cuisine may have been, its practitioners were few and soon perished from imported diseases or interbred into the new Spanish master culture. But in Mexico, indigenous civilization was too highly developed and the populace too numerous to ignore. Despite smallpox and

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war, the pre-Columbian world persiste and mixed with the imported culture viceregal Mexico. This *mestizaje,* "mixing," affected every aspect of Mex can life. But the mélange is nowhere mo noticeable, or more crucially definin than in the kitchen and on the table.

The foremost Mexican gastronom writer of our day, Salvador Novo, e pounds this phenomenon almost ecstat cally in his *Cocina Mexicana o Histori Gastronomica de la Ciudad de Méxic* (Porrua, 1967):

> The encounter was a fortunate one, th marriages were happy, their offsprin abundant. *Atoles* [a category of beverage and cacao drinks benefit from sugar an milk; tortillas, after being fried or sprinkle with chorizo [a Spanish pork sausage], wi transform themselves into *garnacha chalupas, sopes,* tostadas, tacos, ench ladas, *chilaquiles, infladas, molote bocoles, pellizcadas.* Tamales will be fluf ier with lard . . . . Refried beans will b more delicious than plain boiled beans; an beans as well as strips of chili fried wit onion will accept the white, tasty caress c cheese and cream.
>
> The union of corn with cheese will giv birth to *quesadillas;* like Spanish empa nadas, yes, but accented with little bits c chili, or ennobled with squash blossoms c with *epazote* . . . .

It would be possible to go through dis after dish in this manner, sorting out th Aztec and Spanish contributions to each But the most impressive part of th *mestizaje* in Mexican cuisine is how rap idly it took hold, both in agriculture and i the kitchen. Already in Cortés's lifetime the process had permeated all sectors o Mexican life, and by the seventeenth cen tury the invention of new, self-consciously Mexican dishes was pursued at the high est levels of the vicerealm.

In particular, well-born or well-con nected women in convents created many hybrid recipes, notably a whole repertory of elaborate sweets. The greatest of Mexi can sauces, the *mole poblano,* was accord ing to legend invented by a religious, So Andrea de la Asunción, at the convent o Santa Rosa in Puebla. Whether the at tribution is correct or not, the notion o Puebla as the origin of this savant sauce i convincing. A great colonial center Puebla was a cosmopolitan place, open t new things. It was Puebla that welcomed a Chinese girl, the China Poblana, and made her into a folk symbol whose color ful dress is still recognizable to every Mex ican—a charming relic of the seaborne trade with China.

Puebla in the seventeenth century was a hub of new things, just the sort of place where a refined nun would mix chocolate chilies, and imported ingredients, such as

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Chiles Poblanos en Nogada

(Adapted from Virginia Ramos Espinosa's *Los Mejores Platillos Mexicanos,* Editorial Diana, 1976)

- 12 *chiles poblanos*
- 1½ pounds boneless pork shoulder, cubed
- Salt
- 2 cloves garlic, peeled and chopped
- 1 onion, peeled and chopped
- 2 tablespoons corn oil
- ½ cup vinegar
- 2 tablespoons lard
- 1 pound tomatoes, peeled, seeded, and chopped
- 3 tablespoons raisins
- 10 blanched almonds, slivered
- 10 pitted green olives, chopped
- Sugar
- Pepper
- 1 bay leaf, crumbled
- 50 walnuts, shelled (freshly harvested if possible or otherwise soaked in water overnight) and with inner skins removed
- ½ cup crème fraîche
- ¼ cup sherry
- 2 pomegranates

1. It is pointless to make this dish with green bell peppers. Only the actual tapered, mildly hot, big green pepper called *chile poblano*, or "chili of Puebla," will re-create this dish. Toast each one over a direct flame or under the broiler until the skins blacken all over. Then put them in a damp towel or a plastic bag for 15 to 20 minutes. They should now peel easily. After peeling, cut a slit lengthwise but leave the stem end and tip intact. Trim out the internal veins and remove the seeds. Set aside.
2. Cook the cubed pork in lightly salted boiling water to cover, along with half the garlic and onion, for 45 minutes. Drain, reserve the cooking liquid, and chop the pork fine.
3. Heat the corn oil and add the rest of the garlic and all but one tablespoon of the onion. Add the chilies and toss until the onion is transparent. Then add ½ cup vinegar, a cup of water, and salt. Bring to a boil, reduce heat, and simmer until the chilies are cooked through.
4. While the chilies are cooking, finish cooking the stuffing (*el relleno*). Heat the lard in a skillet and add the remaining tablespoon of chopped onion. Sauté until translucent. Then add the chopped pork, chopped tomato, raisins, almonds, and olives. Add ½ cup of the reserved pork cooking liquid, the sugar, salt, pepper, and the bay leaf. Bring to a boil, reduce heat, and simmer until almost all liquid evaporates.
5. Make the walnut sauce (*la nogada*). Chop the nuts very fine and combine with the crème fraîche, or put them in a food processor along with the crème fraîche and process with the metal blade until smooth. Then stir in the sherry and season with a bit of wine. The sauce should be thick but pourable. Thin out with sherry if necessary.
6. Stuff the chilies with the pork mixture and arrange them on a serving platter. Cover with sauce and sprinkle with the pomegranate seeds.

Yield: 6 servings

Note: In a more elaborate and also entirely authentic version of this dish, the filling includes peaches and pears, as well as acitron, the preserved fruit of the bisnaga cactus, all cut in quarters. The stuffed chilies are sometimes coated in flour and beaten egg and then fried before being sauced. Some cooks chop broad-leafed "Italian" parsley and sprinkle it over the sauce along with the pomegranate seeds.

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innamon and coriander, for a sauce to go ith the great Aztec bird, the turkey. If ne final taste of the sauce seems Asian to s, perhaps our taste buds are hinting at a istorical truth. Probably not, but the leg- nd of *mole poblano* as an invented sauce oncocted by a non-Aztec with Spanish nd local pre-Columbian ingredients is it- elf worthy of note. Even if the account is nly a fable, it is a fable that demonstrates ow eagerly Mexicans embrace the idea f a *mestizo*, or "hybrid," origin for their ational cuisine.

What seems clear, in any case, is that ut of the extremely fertile period of Mex- an sauce development in the eighteenth entury, the *mole* (Nahuatl for sauce), hich combines chocolate and chilies, merged firmly identified with Puebla.

I emphasize this because the acme of efinement in classical Mexican cookery is nother Poblano dish that, beyond any oubt, had to be invented at some point fter the conquest because it combines hilies and milk. The chili is the big green *hile poblano*, the chili of Puebla. The ish is called *chile en nogada*. It is an laborate member of a family of dishes hat all involve stuffing *chiles poblanos* ith one thing or another. *Chile en nogada* s stuffed with chopped pork and served in sauce of ground nuts and cream. In some ersions of this dish, peaches and pears, citron (the candied fruit of the bisnaga actus), and other fruits are added to the tuffing. Perhaps this is a relic of a re-Columbian, and therefore pre-pork, tuffed *poblano* dish in which the stuffing as all fruit.

Chile en nogada is still a seasonal dish f late August, but now the timing de- ends on another seasonal fruit, an Old Vorld fruit, the walnut (called *nuez de Castilla* in Mexico to distinguish it from he pecan, which is simply *nuez*). Fresh alnuts and cream bathe the stuffed reen chili, and ruby red pomegranate eeds, also Old World in origin, provide he third color of the Mexican flag. Some eople believe that the patriotic appear- nce of this "Old World" sauce for New Vorld chili stuffed with Old World pork s not happenstance. They say that *chile en ogada* was invented in Puebla for a ban- uet honoring Agustín de Iturbide, the elf-styled emperor of newly independent Mexico, on August 28, 1821. Once again, t doesn't matter if the whole story is true. The story only completes the symbolism f a great dish that is the epitome of a ulture.

Raymond Sokolov is a writer whose spe- ial interests are the history and prepara- ion of food.

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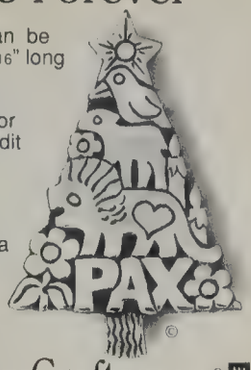

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Hanging Tough

Photograph by Raymond A. Mendez

A female green lynx spider hangs upside down, letting her newly hatched offspring run over her body while she keeps a keen-eyed lookout for any sign of danger. A hunter rather than a web spinner, the green lynx attacks her prey from ambush, using her silk only for her egg sac. Three to four weeks after mating, the female spider picks a spot near the top of a bush or clump of grass and begins the five-hour job of weaving a pouch, filling it with 25 to 600 tiny orange eggs and securing it to nearby leaves and twigs by a maze of fine threads. For the two weeks or so that it takes the eggs to hatch, she waits, suspended head down, her long, spiny legs hugging the bag. She leaves her post only to rush at any creatures, including photographers, that pose a threat.

Green lynx spiders are found throughout the southern United States; the family pictured here was spotted in a roadside shrub in Portal, Arizona.

Born orange, the spiderlings turn bright green after a few days. They are fed and protected by their mother for a little more than a week, then disperse by ballooning. Clinging to a twig, a young spider turns toward the wind, raises the tip of its abdomen, and allows the breeze to carry its silk dragline for two to three feet. Letting go of the twig, it drifts slowly out of sight.—*O. W.*

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AUTHORS

When **Peter C. Lent** (page 50) first got involved in muskox research, little was known about these large ungulates of the north. Involved in projects to introduce muskoxen into various areas, he came in close contact with the animals, sometimes wrestling them into crates for transport. The yearlings in the picture were bound for the USSR (author is at right). Lent recently retired, after twenty-two years with the U. S. Fish and Wildlife Service and the Bureau of Land Management, and is now teaching part-time and trying out the world of free-lance nature and travel writing. One of his projects for the future is to write a book about the history, biology, and management of the springbok, a gazelle of southern Africa. Lent recommends *Arctic Dreams,* by Barry Lopez (New York: Bantam Books, 1987), an enjoyable book about humans and nature in the Arctic, with one chapter devoted to the muskox. For a more detailed study of the behavior and annual cycle of a population of muskoxen in the Canadian Arctic, readers might look for David Gray's *The Muskoxen of Polar Pass,* published in 1987 by the National Museum of Natural Sciences in Ottawa.

Shortly before the back of the moon
as mapped by satellites in the mid-
60s, **William K. Hartmann** (page 68)
lped identify a large impact structure
the edge of the side facing the earth.
though 540 miles wide, the Orientale
sin had never been recognized be-
use it is seen edge-on. This discovery,
ong with his experiences on the *Mari-*
r 9 team that mapped Mars in the
rly 1970s, led Hartmann to wonder
out large impacts and eventually to
opose that a catastrophic collision with
e earth could have created the moon.
rly in his career as a planetologist,
artmann began painting scenes of dis-
nt worlds to help convey the discover-
in the solar system to others. To make
illustrations as realistic as possible,
has traveled on painting expeditions
some of our planet's most barren land-
apes. His artwork and writings appear
many publications, and he is currently
orking on a popular book on the history
the earth. Hartmann is now a senior
entist at the Planetary Science Insti-
te, a division of Science Applications
orporation in Tucson, Arizona. The au-
or recommends Stuart Ross Taylor's
ok *Planetary Science: A Lunar Per-*
ective (Houston: Lunar and Planetary
stitute, 1982) and a book by Clark
apman and David Morrison, *Cosmic*
atastrophes (New York: Plenum
ess, 1989).

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The largest wilderness area in the lower forty-eight states, the Frank Church–River of No Return Wilderness in Idaho, is blanketed by several feet of snow for up to eight months a year, and **Patricia H.** and **Gregory D. Hayward** (page 78) have seen much of it on cross-country skis. Alumni of the University of Idaho, Pat has a bachelor's degree in wildlife ecology and Greg has just finished his doctorate. They met on a 1980 owl study that led to the discovery of breeding boreals in the Rockies, and from 1984 to 1988 they persevered at the demanding task of tracking these peripatetic birds. The job, says Greg, was "far from work. My fondest memories are of skiing through miles of unbroken powder knowing that Pat was the only other human for more than twenty miles or listening at night under a star-filled sky to the soft call of a boreal owl." He intends to continue to monitor the boreal owl population in managed forest systems and to study the ecology of old-growth forests. Until recently, Pat, an avid horsewoman, spent almost all of her leisure time participating in dressage and eventing. But most of the Haywards' attention now goes to their son, born in June. Distance running keeps Pat in shape for chasing owls, horses, and little boys. The authors recommend two books for readers who wish to learn more about boreals and other owls of the Northern Hemisphere: Paul A. Johnsgard's *North American Owls* (Washington: Smithsonian Institution Press, 1988) and Heimo Mikkola's *Owls of Europe* (Vermillion: Buteo Books, 1983).

Naturalist-photographer **Raymond Mendez** (page 116) admits to a lifelo fascination with insects and arachni "I've never had the irrational fear bugs that so many people have," he sa "To me, they're the ultimate machi perfectly streamlined. And unlike h mans, where the machinery is cover up by skin, insects have their skelet on the outside so you can see the wo ings." After studying biology in colle Mendez spent seven years in the en mology department of the Americ Museum of Natural History, working taxonomy. "It had been my dream work at the museum," he says, "b eventually I realized the thrill was go because the insects were dead—the m chines were broken." Today he uses skills as a photographer and artist, well as his knowledge of entomology, pass on his love of "bugs" to others. H has designed an insect exhibit for t Staten Island Children's Museum and working on an insect zoo for the Smiths nian Institution in Washington, D. C. capture the green lynx spider and her b bies for this month's "Natural M ment," Mendez used a 105-mm mac lens on a Nikon F3.

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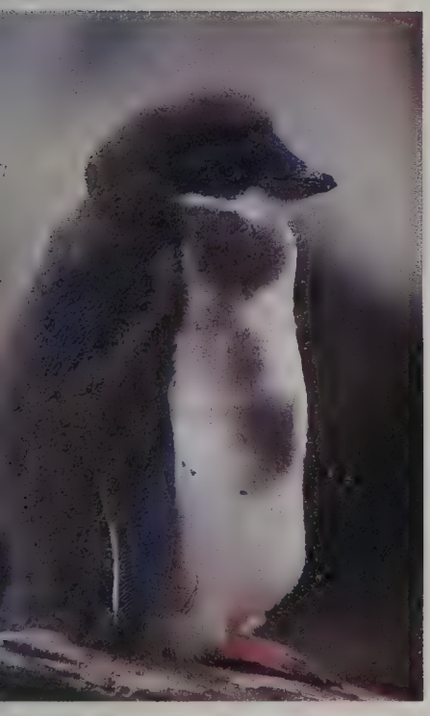
DECEMBER 1989

COVER: *Two-month-old maiasaurs follow in the footsteps of a protective parent. Story on Page 60. Illustration by Donna Braginetz.*



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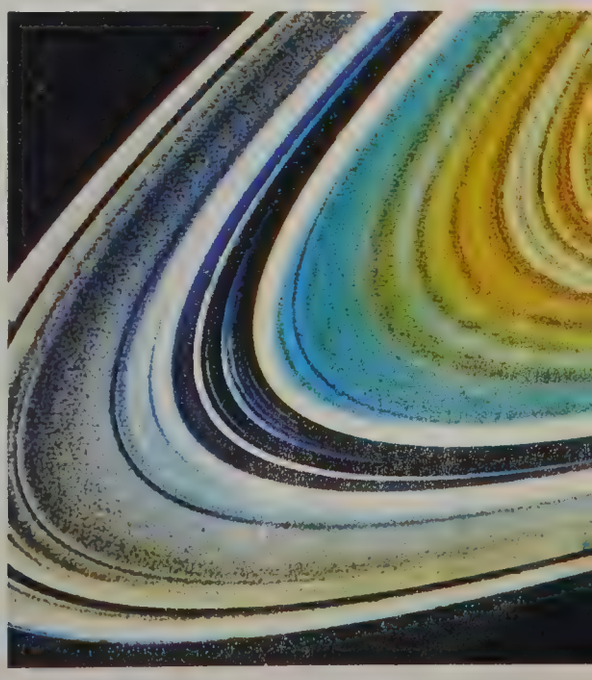

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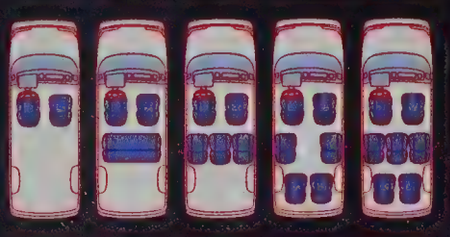

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FEAR OF FALLING

Jared Diamond's August 1989 article, "How Cats Survive Falls from New York Skyscrapers," helped explain something I observed more than twenty-five years ago as a young boy delivering newspapers in southern Wisconsin. I had paused on my route to watch two gray squirrels chasing each other in the tops of some huge American elms. The trees formed an arch of branches 80 to 100 feet over the city street. To my horror, one of the squirrels fell, making a dull "splut" sound on the asphalt surface below. The squirrel lay motionless while I tried not to imagine what it must have felt like. After about fifteen seconds, it suddenly got up, ran to the nearest tree, and scampered up the trunk as though nothing had happened.

Once again, natural selection obviates the need to reach for the word "miracle."

TERRELL D. RICH
Dickinson, North Dakota

Just a few days after I read Jared Diamond's piece, my husband and I accompanied several children to an ice cream store. Across the street, a cat happened to be leaning precariously far out of a second story window. The children were concerned for its safety, and my husband was in the process of reassuring them that, if the cat did fall, it would probably not sustain any serious injuries unless the fall was quite a bit greater than from the second story.

My rule about never correcting a spouse in public quickly fell to the wayside. This one I could not pass up.

"Actually, Bill, recent studies in feline pesematology indicate that . . . ," piped I.

"Feline *what*?!"

"Pesematology. It's the science of falling cats," I responded with surprising cool. "Anyway, it seems that there are three primary reasons why a cat's probability of surviving a fall is greater than a human's and actually *increases* above seven stories." (My husband's lower jaw fell somewhat.) "You see," I grandly pronounced with the arrogance of someone who is praying he won't ask how an ant walks away from the incredible fall (relative to its own body size) of being blown off my finger, "cats not only have an inne ear gyroscopic capability, which enable them to right themselves after falling onl a few feet, but they also assume the sprea position of a flying squirrel or paratroope upon reaching terminal velocity at abou seven stories, which both distributes the weight and decreases their velocity. An of course, they're considerably smalle than people, so they impact the groun with less force."

There was a short silence by the chi dren before they returned to the giggles eating ice cream, but I'm quite sure tha my husband of these many years looked a me with new awe.

Now, about the ant . . .

LINDA L. FILLIN
Portola Valley, Californi

ON FELIPE POEY

In "Room Without a View" (Septem ber 1989), an unfortunate typographica error (Poly instead of Poey) robbed th Cuban naturalist Felipe Poey of his wel deserved credit.

It would be fair and educative to run brief biographical note on this Lati American ichthyologist, whose prolifi work was highly regarded by the Euro pean scientific community of his day.

JOSÉ ALCIDES FERNÁNDE
New York, New Yor

EDITOR'S NOTE: Called the Father of Cu ban Zoology, Felipe Poey (1799–189 was an entomologist and one of the fore most ichthyologists of the nineteenth cen tury. Poey described 389 species of fish many of which are the type specimen now housed at the Harvard Museum o Comparative Zoology, the Academy o Natural Sciences in Philadelphia, and th Smithsonian Institution. Except for stud ies in Paris, Poey spent his life in his nativ Havana, where he was director of the Zoo logical Museum.

FORBIDDEN MOURNING

Reading Nancy Scheper-Hughes' "Death Without Weeping" (Octobe 1989), I was reminded of one Jewish tradi tion that forbids formal mourning for child less than a month old—a long

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enough time to allow even a death resulting from an infection at the time of circumcision to be included in the prohibition. This custom always struck me as humane and not at all cruel in a world where infant death is common, and that motive of humanity appears to be echoed in Scheper-Hughes's Brazilian society.

J. Kates
Fitzwilliam, New Hampshire

I read Nancy Scheper-Hughes's article with much *saudade* [homesickness], for I too was a Peace Corps volunteer in the northeast of Brazil during the sixties. The town my wife and I worked in was not a shantytown on the outskirts of a big town or a big marketplace. Our town was just a poor little town where almost everyone was in similarly dire straits. Hardly anyone had even been as far from home as the coast. But the townspeople had attitudes about life and death that were similar to those of the author's town.

One of the first questions we asked the townspeople was about the constant ringing of the church bells, and we received the same answer the author received: another angel was going to heaven. I spent lots of time writing letters and trying to explain to people back home how differently the Brazilians seemed to think, especially about life and death. In the northeast the answer to the question, "How many children do you have?" had a standard form: "X children, Y living." I appreciate the author's writing because it shows that she pursued the questions that came from her experience in Brazil, something I wish I had done.

One piece of information I'd like to furnish: the quotation with which the author begins her article seems to be from the song "Disparada" (stampede), by Geraldo Vandré. The song won the grand prize at the Brazilian Popular Music Festival of 1965, tied with Nara Leão's "A Banda," which we found Herb Alpert playing when we came home.

Richard J. Bandera
South Bend, Indiana

A Matter of Tequila

Raymond Sokolov perpetuated an old misconception when he stated that tequila is fermented pulque ("Insects, Worms, and Other Tidbits," September 1989). It's an easy mistake to make for anyone familiar with the distillation of wine into brandy, but it's totally wrong.

For one thing, tequila comes from *Agave tequilana* (also known as blue agave), a species of agave (of which there are about 400) totally separate from *A. salmiana, A. atrovirens,* and *A. americana,* which are most commonly tapped for pulque. Secondly, although it's possible to get the raw sap (*aguamiel*) from *A. tequilana,* the process used to make tequila at no time involves the production of either *aguamiel* or pulque.

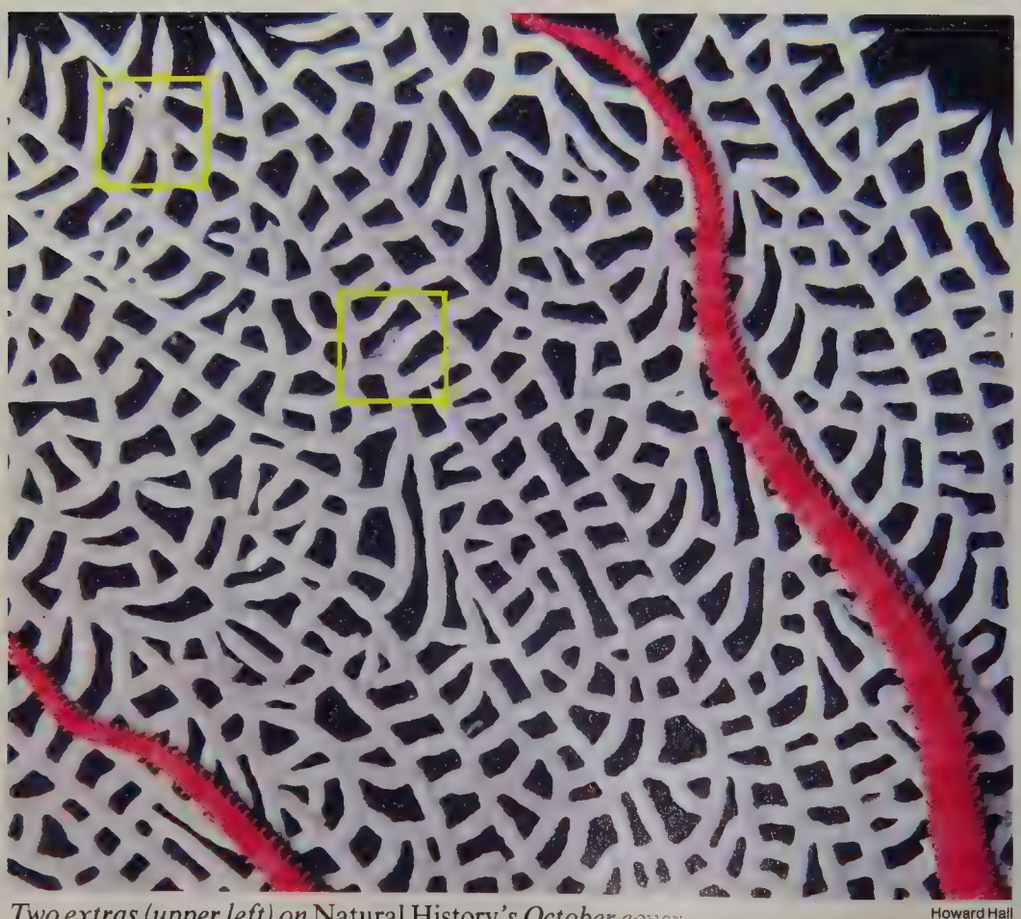
A. tequilana is harvested at a young age (relative to those species used for pulque which are only tapped at the very end of the plant's life). The leaves are chopped off, leaving only the heart. These hearts, usually weighing more than 100 pounds each, are then cooked in large steam ovens (or roasted underground) in large quantities to turn their starches into sugars. The juices are then pressed out, more sugar is added, and the mixture is fermented to produce tequila.

Gregory B. Cunningham
Clearwater, Florida

Covert Creatures

The cover on the October 1989 issue of *Natural History* is a beautiful example of two sea creatures, a brittle star and a sea fan. Two other creatures were not discussed in the accompanying article or cover caption. A tiny flea is located in the upper left hand corner, and about one inch to the right and one inch below the flea there appears to be a tiny green slug.

Francis W. Wing
Dallas, Texas



Two extras (upper left) on Natural History*'s October cover*

Howard Hall

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Not by Grass Alone

When a vegetarian diet just doesn't satisfy, herbivores turn to other, sometimes unorthodox, food sources

by Robert W. Furness

I first visited the Shetland Islands in 1971, on a school trip to band seabirds. These remote isles off the north coast of Scotland captivated me with their magnificent cliffs, spiky hills, soggy blanket of moorland, and the ubiquitous seabirds scurrying back and forth from the sea carrying fish to their chicks. Years later I returned there to study the breeding habits of skuas, the dark, hawklike seabirds of the northernmost regions of Britain, Iceland, and the Faeroe Islands. My research took me to Foula, a dot of an island, only three miles long by two and a half miles wide. It still has no electricity, town water, sewers, or shops. Foula's only inhabitants are about thirty crofters, who make a meager living raising sheep, a few cows, and some Shetland ponies, and about 3,000 pairs of skuas.

The skua is notorious for its piratical behavior. It will chase and harass other seabirds until the victim—out of fear or exasperation—drops its food, often right into the tormentor's mouth. Skuas also steal other birds' eggs and young and, in fact, eat any live animals they can overpower.

I soon got used to being hit on the head by the angry birds. They would swoop down and slap me with the back of their feet as they whizzed by inches above my head. Nonetheless, I found skuas rather less fierce than their reputation suggested. Usually, as long as I looked at them as they dived, they missed me. Their reputation as robbers and predators, too, probably is exaggerated. At Foula, most of the skuas lived by catching sand eels, small fish that shoal at the sea surface in vast numbers around Shetland, or at least used to in the days before industrial fishing. When sand eels were scarce, the skuas turned to scavenging discarded haddock and whiting thrown away by the Shetland trawler fleet. It was an easy and effective way of making a living, and the Foula skuas bred with great success. As part of my research I marked and monitored several hundred skua nests, visiting them every three or four days. Nest mortalities were rare. A few birds clumsily rolled eggs out of the nest (but unlike gulls, they failed to retrieve them). A few eggs were infertile, and a few chicks died while emerging from the shell. However, in one part of my study area I discovered several clutches of eggs that seemed to have been destroyed during incubation. Only fragments of shell remained. A predator would seem to be responsible, but what predator could brave the attacks of skuas and eat their eggs? I was stumped by this. Foula is isolated from mainland Shetland by twenty miles of turbulent ocean, and the island has no large mammalian predators. There are a few feral cats, but they live mainly among boulder fields below the cliffs, well away from skua territories. There are no minks or otters. Visiting birds of prey are chased away from the island by the skuas, while the cliff-dwelling crows and ravens never venture inland into skua territories until the skuas migrate south in the fall.

Since all the nests that had been attacked were in the area where Foula's semi-feral Shetland ponies grazed, I began to suspect the ponies were snacking on skua eggs. When I mentioned this to the crofter who owned the ponies, he laughed at my preposterous idea. Ponies are herbivores, he said, and herbivores have teeth and digestive tracts specifically designed for processing plant food. They couldn't eat birds' eggs even if they wanted to. When I wrote my research report, I listed the cause of the loss of these eggs as "unknown." I didn't want my professor to mark me down for producing fanciful ideas about bird-eating ponies.

The next summer I returned to Foula and encountered even more bizarre happenings. While banding tern chicks, I found some young birds that had had one wing neatly amputated. Others had one or both legs severed, but the wounds had healed and the amputee chicks continued to grow. Still other chicks lay dead in the colony, their heads severed. In previous years we had recorded one or two chicks injured in this way but had not thought much of it. In 1974 we found 50 maimed chicks out of a colony of about 2,000. In 1975 the colony was bigger—about 4,000 birds—and some 200 chicks had been attacked. Obviously something was attacking the young terns in a very precise manner. Whatever it was did not attack skua chicks. Perhaps the aggressive skuas could keep the predator away from the chicks.

The local people were as puzzled as I was. Some suggested it might be the work of a visiting otter from Shetland mainland or of hedgehogs (which usually feed on insects but do have a reputation for gastronomic experimentation). One visiting ornithologist, who didn't believe an animal could sever the limbs so cleanly, raised the possibility that a deranged person wielding a sharp pocketknife was on the loose. The whole thing seemed inexplicable on the basis of what was known of animal natural history.

Then one of the islanders reported seeing a sheep pick up a tern chick in its mouth and shake it, biting through the spine until the severed body fell to the ground. The sheep then ate the head. After hearing this, I spent hours at a time carefully watching the sheep and eventually—it took a couple weeks—saw it for myself! Three times, I observed a sheep force a tern chick down on its back, bite off one or both of its legs, eat them, and then continue grazing without further attention to the chick. I knew it wasn't the

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Foula's tern chicks, like this one, regularly fall prey to the island's hungry sheep. Robert W. Furne

same sheep all three times because of the highly variable wool color and patterning of the Shetland sheep on Foula. The tern chicks made little or no attempt to get away from the sheep. Their response to being nudged by the sheep's mouth was to lie still.

When I told other seabird biologists and experts on herbivores about the predatory sheep on Foula, most reacted with amazement, and at least a hint of incredulity. Not only are sheep herbivores, they're picky eaters, carefully choosing the grass they eat. Devouring birds was seen as very odd behavior, indeed. Lacking any film of the sheep actually attacking a chick, I was reluctant to publish my observations at that time. However, it was not my last encounter with carnivory among herbivores.

In 1982 I visited Rhum, an island off the west coast of Scotland near Skye, to study Manx shearwaters. More than 100,000 pairs of shearwaters—the largest colony of the species in Europe—nest 2,500 feet up on the steep slopes of the Rhum mountains. Their unusual habit of nesting at high elevation was thought to be due to the large numbers of rats on Rhum, particularly along the coast. On adjacent islands, shearwaters, which are nocturnal burrow nesters, appeared to be declining and badly affected by nest predation by rats. Rhum is a national nature reserve, and I was asked to set up a study of the shearwaters to see if rats were a problem and whether conservation measures were required to protect the birds. As it turned out, rats were not the reason shearwaters nested on cliffs. High elevation simply provided better drainage and less risk of flooding in the burrows.

As part of that study, teams of Earthwatch volunteers on Rhum helped me monitor changes in the number of burrows over the years, as well as band adults and chicks. We worked on the colony slopes in August and September, about the time that the chicks would begin to explore the surface near the burrows and could therefore be easily caught. To our surprise we found large numbers of headless shearwater corpses scattered throughout the colony. My first thought was that one of the many eagles on the island was attacking shearwaters at night and, for some reason, dropping the bodies after it had removed the heads. This seemed farfetched, but what other explanation could there be?

Because of the fertilizing effect of the birds' droppings, the grass around the shearwater colonies is much lusher than elsewhere on the hilltops. These shearwater "greens" are preferred grazing areas for the deer on the hills. While walking across the hills on Hallival one day, I spotted a hind carrying a struggling shearwater, its head inside the hind's mouth, its body dangling. The bird was flapping its wings and "paddling" with its feet. With side-to-side motion of its head, the hin shook the shearwater vigorously until th bird fell to the ground, its body severed a the neck. I chased the deer away in orde to retrieve the corpse. As I began to ap proach, the deer swallowed the head. O another occasion, a hind was observe treating another shearwater in exactly th same way. In this instance, after swallow ing the severed head, the hind walke away ignoring the rest of the corpse. A young stag then walked up to the corps and began to chew the legs. After abou five minutes, he turned his attention to th carpal joints in the wings, carrying th corpse as he followed the group of hinds When I retrieved the remains of this bird I found that the bone of each leg had bee excised from the skin and sinews, leavin the feet dangling. The carpal joints of th wings had been opened and the bone care fully removed without loss of feathers skin, or flesh. This deer would have re ceived top marks in an examination o dissection technique. We found dozen more corpses that had been attacked i the same manner and saw deer eating th limbs of shearwater chicks on many occa sions. The corpses that the deer left wer quickly scavenged by eagles, ravens, an crows, so that no evidence of the attack remained after twenty-four hours or so other than some plucked feathers and de boned wings abandoned by the birds.

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After this experience on Rhum, I published my observations of deer and sheep eating seabird chicks in a leading scientific journal. The subject drew media attention, and this brought out other accounts of predatory herbivores. Occasional carnivory among herbivores, it seems, is not new. For example, in 1905, Perthshire minister John Sinclair wrote that "deer—more especially old hinds—gobble up grouses' eggs in spring. Stags have also been known to pursue . . . young grouse, and gobble them up."

In his studies of skuas in the Faeroe Islands in 1960 and 1961, Dick Potts, director of research at the Game Conservancy Trust, wrote that cattle ate "at least 30" skua eggs, and that on Nolsay, cows had "often been seen to eat arctic tern chicks and eggs."

The eminent British naturalist and author Ronald Lockley reported in his book *I Know an Island*, published in 1938, that sheep on North Ronaldsay in Orkney would eat the legs of dead birds washed up on the beach. Lockley speculated then that this habit had arisen because of "a need of lime and phosphate that gave the sheep this curious appetite. Probably there is not enough of these elements in their normal diet of seaweed."

Most likely, herbivores resort to carnivory now and again to meet their mineral requirements. Most of the Scottish moorland is low in calcium, particularly on the wet and acidic west coast where peat overlies volcanic rock.

What I find particularly intriguing is how the deer learn to eat parts of birds to obtain minerals. Can they smell calcium or phosphate or do they discover the source by chance? Do young deer learn the technique of excising bone from birds from parental example? Given the difficulty of detecting the habit, is it widespread on the Scottish moors?

There may be a physiological basis for carnivory among herbivores. In a study at the University of Melbourne, Australia, cattle fed a phosphate-deficient diet tried to eat plaster of Paris made with bone extract, while ignoring plaster of Paris that did not smell of bone.

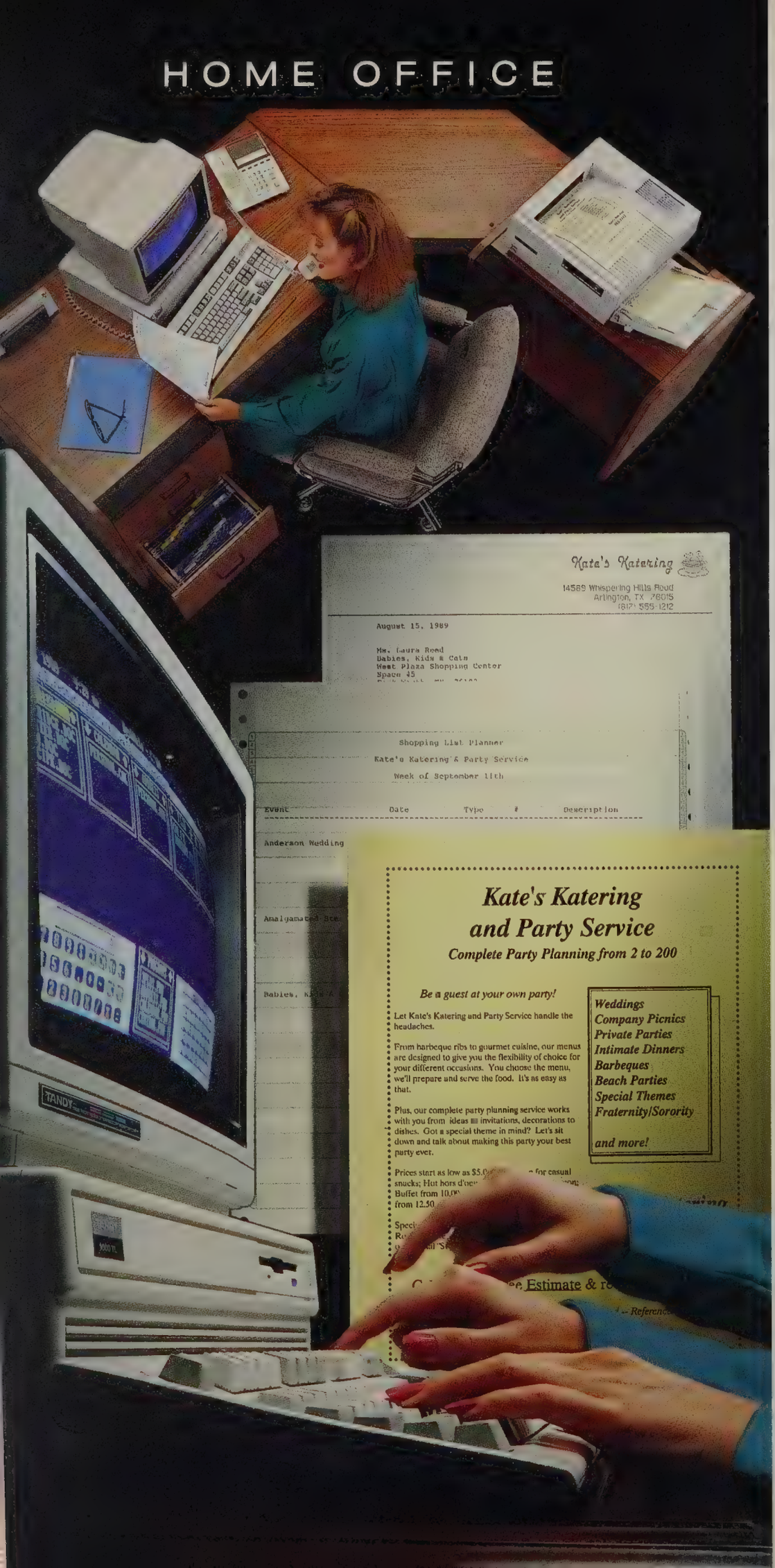
That cows, and presumably other herbivores, have evolved an ability to smell and locate sources of bone to alleviate mineral deficiency implies that this ability had adaptive value. My observations of sheep and deer regularly attacking seabird chicks in a very characteristic way in order to obtain bone, and the numerous anecdotal records that have been traced in literature and by word of mouth, indicate that animals do make use of this ability. The places where it has been recorded share geological, vegetational, and climatic features that result in calcium- and phosphorus-deficient plant diets.

It is well known that herbivores will seek out nonplant food sources to get all the nutrients they need, most commonly by using salt licks and eating soil. For example, in north-central New Hampshire, where vegetation is low in sodium, deer will lick the salt used for snow and ice control on roads. On Africa's Mount Kenya, American buffaloes use their horns to dig up iron-rich clods of soil, which they eat. Clearly, herbivores do what they have to do when a vegetarian diet is not enough.

Robert W. Furness is a senior lecturer in zoology at the University of Glasgow, Scotland.

Red deer in Scotland occasionally have an appetite for more than grass.

Francisco Erize; Bruce Coleman Inc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Tom Miner Basin, Montana

by Robert H. Mohlenbrock

In southern Montana, off U. S. Highway 89, Forest Service Road 63 curls for about twelve miles through Tom Miner Basin and ends at the Tom Miner campground. From there, a hiking trail framed by rugged mountains follows a creek westward on a steady, 2.5-mile climb to Buffalo Horn Pass. At the pass another trail leads north toward 10,269-foot Ramshorn Peak, passing mountain meadows dotted with Indian paintbrushes, red beardtongues, and yellow mule-ears. Along the mountain streams and ridges grow lodgepole and whitebark pines, Engelmann spruce, Douglas fir, and quaking aspen. A more startling sight, however, are the standing petrified tree trunks and stumps, some more than eight feet tall and four feet across, that are interspersed in the living vegetation. Other fossilized logs are strewn across the terrain.

This is the northern end of Gallatin Petrified Forest, which extends for fifty miles from Montana's Gallatin National Forest south into Yellowstone National Park, Wyoming. To the southeast there is a second petrified forest of standing trees in the bluffs along the Lamar River, a few miles from its confluence with the Yellowstone. Trapper Jim Bridger, tongue in cheek, described those trees during the 1830s, reporting "peetrified birds a sittin' on peetrified trees a singin' peetrified songs in the peetrified air."

The two petrified forests were apparently formed following the same volcanic eruptions, sometime during the Eocene, the geological epoch from about 60 to 40 million years ago. Underground water, often hot, picked up silicon dioxide (quartz) from the layers of volcanic material and circulated through trees buried by the eruptions. The water filled the cavities of the empty wood cells and deposited minerals on the tough cell walls. As a result, even microscopic details of the wood were preserved in stone.

William Henry Holmes, a member of the U. S. Geological and Geographical Survey of the Territories in the 1870s, was the first to write about the fossil formations of the Yellowstone area in some detail. He described the petrified trees as resembling pillars of some ancient temple. After observing that standing trees were exposed at different levels on some cliffs, Holmes suggested that ten or more forests had been buried in successive layers of volcanic ash.

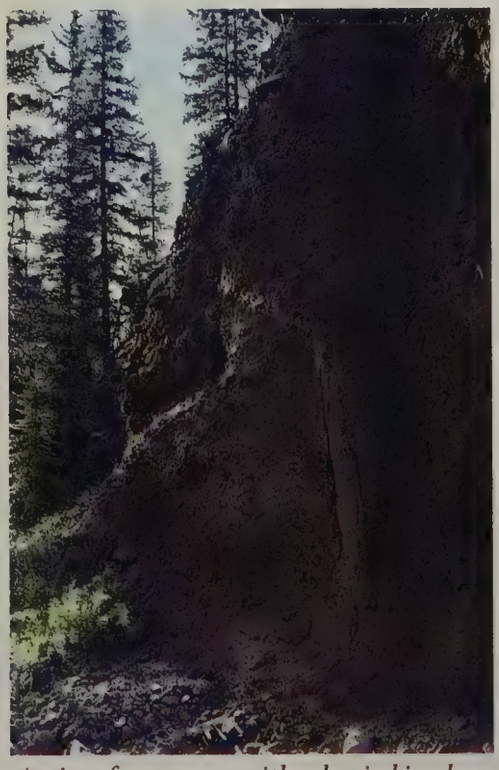
A puzzle soon emerged, however. In 1899, Frank Hall Knowlton, a paleobotanist with the U. S. Geological Survey, identified nearly 150 species of plants in the petrified forests. While the living forests of the Yellowstone area are now dominated by coniferous plants, relatively few of these, mostly pines and redwoods, were in the fossil forests. Instead, Knowlton discovered a remarkable diversity of species. Many of the trees, such as sycamores, magnolias, chestnuts, maples, dogwoods, walnuts, hickories, elms, and willows, were apparently relatives of similar hardwood species that live in temperate regions today. Others seem to have been closely related to plants now typical of the tropics and subtropics. These included avocados, figs, greenheart ocoteas, acacias, and breadfruits. (More recently, botanist L. H. Fisk examined the pollen grains buried in the layers containing the fossil trees and was able to add other temperate spe-

Aspens fill the meadow and various conifers dot the slopes in this corner of Tom Miner Basin, below. Left: One of the many petrified trees formed by volcanic eruptions in the area during the Eocene epoch

Photographs by Erwin and Peggy Bauer

cies to the ancient flora: larch, spruce, yew, holly, alder, basswood, and ash.)

Botanists who have studied the area have commented on this unusual mixture of temperate and tropical species, which apparently grew side by side. Princeton geologist-paleobotanist Erling Dorf investigated the petrified forests nearly three decades ago and theorized that during the Eocene, the topography of the Yellowstone region consisted of a series of broad, flat river valleys separated by gently rolling hills that rose some 1,500 feet above the valley floors. The overall climate in the area, he suggested, was essentially the same as that found on the Gulf Coast of the southeastern United States today, ranging from subtropical in the valleys to warm–temperate in the surrounding hills. As a result, he concluded, both tropical and temperate species could have overlapped, especially in the valleys.



Ancient forests were either buried in place or transported vertically.

Then, Dorf continued, volcanoes began to erupt east and northeast of the region, showering rocks and ash over the forests in the valleys and burying the tree trunks up to a height of fifteen feet. Basing his ideas on a contemporary study of forest regeneration, Dorf estimated that about 200 years after the volcanoes erupted a new forest began to grow. The new growth took root in the volcanic material that had buried the previous forest. Measuring the growth rings of some of the standing fossil stumps, Dorf calculated that the new forest was about 500 years old when another series of volcanic eruptions buried it. This process, he concluded, happened again and again, with at least twenty-seven distinct forests of petrified trees formed in layer-cake fashion over 20,000 years. Dorf estimated that these layers, now being exposed through erosion, are more than 1,600 feet deep.

Like most researchers, Dorf took the presence of standing trunks and stumps as evidence that the fossil forests had been buried in place by volcanic debris. Recently, however, Georgia State University geologist William J. Fritz, studying the effects of the Mount Saint Helens eruptions in Washington in 1980, found that tree stumps were often transported and deposited vertically by mud flows. He wondered if this had also happened in the Yellowstone area during the Eocene, which would explain why temperate and tropical species were mixed together.

Analyzing the material in which the fossil forests had been buried, Fritz found that only about 10 percent of it was made up of hot volcanic rock. The remainder, containing most of the fossilized wood, consists primarily of rounded conglomerate rock, which could only have been deposited by sedimentary processes in a volcanic environment. Fritz also noted that, contrary to Dorf's hypothesis of gently rolling hills, some geologists today believe that during the Eocene the mountains in the Yellowstone region rose 8,000 to 10,000 feet above the valley floors.

Fritz hypothesizes, therefore, that mud flows originated high on the flanks of volcanoes, where coniferous and other cool–temperate trees were growing. Fed by rain associated with the volcanic eruptions, and probably by melting snow cover, the flows uprooted trees in the higher elevations and transported them down into the hotter valleys. Fritz suggests that some of the uprooted stumps were deposited vertically amid the tropical species, which were being covered in place by the volcanic rock and ash.

The trees transported by the mud flows would probably have had their roots and branches broken off and their bark stripped and replaced by a mud casing. They also may have been deposited upside down. Stumps buried in place, instead, could have retained well-developed root systems and would more likely be upright. A good test of Fritz's hypothesis would be to see if the trees buried in place were the tropical species, while those that appear to have been transported were the temperate species.

In studying the petrified forests, Fritz also came to challenge Dorf's hypothesis that many successive forests were buried one above another in layer-cake fashion. Rock layers containing standing petrified trees usually cannot be followed for any distance. The layers are interrupted by zones of sedimentary rock in places where, Fritz believes, air-fall ash, wood, leaves, and plant litter were washed into streams and lakes.

"This Land" highlights the biological phenomena of the 154 U. S. national forests. Robert H. Mohlenbrock is Distinguished Professor of Botany at Southern Illinois University at Carbondale.

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The Horn of Triton

In a universe shaped by general laws, individuals still play unpredictable and wondrous roles

by Stephen Jay Gould

The arguments of "iffy" history may range from the merely amusing to the horribly tragic. If Mickey Owen hadn't dropped that third strike, the Dodgers might have won the 1941 World Series. If Adolf Hitler had been killed in the Beer Hall Putsch, the alliances that led to World War II might not have formed, and we might not have lost our war fleet at Pearl Harbor just two months after Owen's miscue.

I don't think that we would be so fascinated by conjectures in this mode if we felt that all things could happen in history. Rather, we accept certain trends, certain predictabilities, even some near inevitabilities, particularly in war and technology, where numbers truly count. (I can't imagine any scenario leading to the victory of Grenada over the United States in our recent one-day conflict; nor can I conjecture how the citizens of Pompeii, without benefit of motorized transport, could have escaped a cloud of poisonous gases streaming down Mount Vesuvius at some forty miles per hour.) I suspect, in fact, that our fascination with iffy history arises largely from our awe at the ability of individuals to perturb, even greatly to alter, a process that seems to be moving in a definite direction for reasons above and beyond the power of mere mortals to deflect.

In opening *The Eighteenth Brumaire of Louis Bonaparte,* Karl Marx captured this essential property of history as a dynamic balance between the inexorability of forces and the power of individuals. He wrote, in one of the great one-liners of scholarship in the activist mode: "Men make their own history, but they do not make it just as they please." (Marx's title is, itself, a commentary on the unique and the repetitive in history. The original Napoleon staged his *coup d'état* against the Directory on November 9–10, 1799, then called the eighteenth day of Brumaire, year VIII by the revolutionary calendar adopted in 1793 and used until Napoleon crowned himself emperor and returned to the old forms. But Marx's book traces the rise of Louis-Napoleon, cousin of the emperor, from the presidency of France following the revolution of 1848, through his own *coup d'état* of December 1851, to his crowning as Napoleon III. Marx seeks lessons from repetition, but continually stresses the individuality of each cycle, portraying the second in this case as a mockery of the first. His book begins with another great epigram, this time a two-liner, on the theme of repetition and individuality: "Hegel remarks somewhere that all facts and personages of great importance in world history occur, as it were, twice. He forgot to add the first time as tragedy, the second as farce.")

This essential tension between the influence of individuals and the power of predictable forces has been well appreciated by historians, but remains foreign to the thoughts and procedures of most scientists. We often define science (far too narrowly, I shall argue) as the study of nature's laws and their consequences. Individual objects have no power to shape general patterns in such a system. Walter the Water Molecule cannot freeze a pond, while Sarah the Silica Tetrahedron does not perturb the symmetry of quartz. Indeed, the very notion of Walter and Sarah only invites ridicule because laws of chemical behavior and crystal symmetry deny individuality to constituent units of larger structures. What else do we mean when we assert that hydrogen and oxygen make water or that silica tetrahedra sharing all their corner oxygen ions form quartz? (We could scarcely speak of a law if Ollie Oxygen willingly joined with Omar but r
fused to share with Oscar because the
had a fight last Friday.) No actual quar
crystal has a perfect lattice of conjoine
tetrahedra; all include additions and di
ruptions known as impurities or imperfe
tions—but the very names given to thes
ingredients of individuality demonstra
that scientific content supposedly lies
the regularities, while uniquenesses of pa
ticular crystals fall into the domain of ho
byists and aestheticians.

(I don't mean to paint the world of sc
ence as a heartless place of perfe
predictability under immutable laws. W
allow for a great deal of play and doul
under the guise of randomness. But ra
domness is just as hostile to the notion
individuality. In fact, classically rando
systems represent the ultimate denial
individuality. Coin-flipping and dic
throwing models rest upon the premis
that each toss or each roll manifests th
same probabilities: no special circun
stances of time or place, no greater chanc
of a head if the last five tosses have bee
tails, or if you blow on the coin and sa
your mantra, or if Aunt Mary will die as
consequence of your failure to score—
other words, no individuality of particul
trials. Individuality and randomness a
opposing, not complementary, concepts—
and although they both oppose the idea
clockwork determinism, they do so in e
tirely different ways.)

Natural history does not share this co
sensus that individual units with partic
lar legacies cannot shape the behavior an
future state of entire systems. Our profe
sion, although part of mainstream scienc
since Aristotle, grants to individuals th
potential for such a formative role. In th
sense, we are truly historians by practic
and we demonstrate the futility of disc

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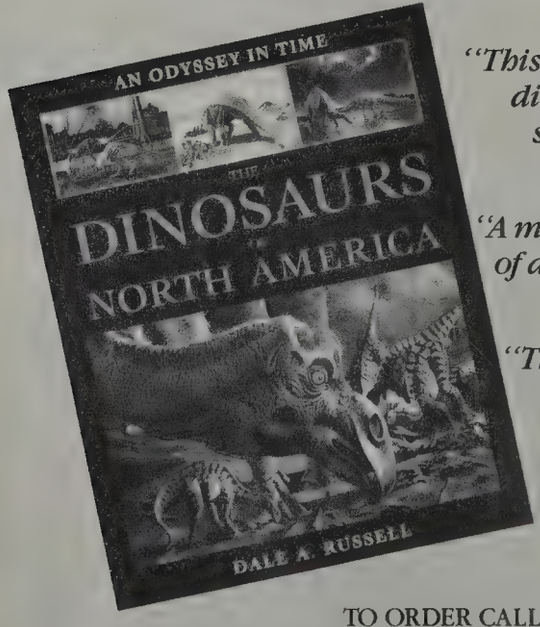

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plinary barriers between science and the humanities. We should be exploring our marked overlaps in explanatory procedures, not sniping at each other behind walls of definitional purity.

Natural history stands in the crossfire and should provoke a truce by reaching in both directions. Individual organisms can certainly set the local history of populations and may even shape the fate of species. Walter the Walrus and Sarah the Saimiri are friendly and congenial, rather than risible, concepts (and may be actual creatures at the municipal zoo). Two recent cases of extraordinary (although not particularly likable) individuals have led me to consider this theme and to grant more attention to the vagaries of one in my profession.

1. Jane Goodall's quarter century with the chimpanzees of Gombe will rank forever as one of the great achievements in scientific dedication combined with stunning results. With such unprecedented, long-term knowledge of daily history, Goodall can specify (and quantify) the major determinants of her population's fate. Contrary to our intuitions and expectations, the demography of the Gombe chimps has not been set primarily by daily rhythms of birth, feeding, sex, and death, but by three "rare events" (Goodall's words), all involving mayhem or misfortune: a polio epidemic, a carnage of one sub-band by another, and the following tale of one peculiar individual.

With odd and unintended appropriateness as we shall see, for the word means "suffering," Goodall named one of the Gombe females Passion. Goodall met Passion in 1961 at the outset of her studies. In 1965, Passion gave birth to a daughter, Pom, and, as Goodall remarks (all quotes from *The Chimpanzees of Gombe*, Harvard University Press, 1986), "thereby gave us the opportunity to observe some extraordinarily inefficient and indifferent maternal behavior."

Nonetheless, Pom and Passion formed a "close, cooperative bond" as the daughter matured. In 1975, Passion began to kill and eat newborn babies of other females in her band. She could not easily wrest a baby from its mother and failed when acting solo, but Passion and Pom together formed an efficient killing duo. (Goodall observed three other "cannibalistic events" during nearly thirty years of work, all directed by males toward older chimps of other bands; Passion's depredations are the only recorded incidents of cannibalism within a band.) During a four-year period, Passion and Pom, in sight of observers, killed and ate three infants by seizing them from their mothers and biting

through the skull bones (sorry, but nature isn't always pretty, and I hate euphemisms). They may have been responsible for the deaths of seven other infants. During this entire period, only one female successfully raised a baby. In studying Goodall's curves of Gombe demography, the depredations of Passion have as great an impact as any global force of climate or disease. Moreover, the effects are not confined to the short years of Passion's odd obsession (for reasons unknown, she stopped killing babies in 1977), but propagate well down the line. Since only one female was raising a baby in 1977, nearly all were in estrus, thus prompting a baby boomlet and sharp rise in population when Passion stopped her cannibalism.

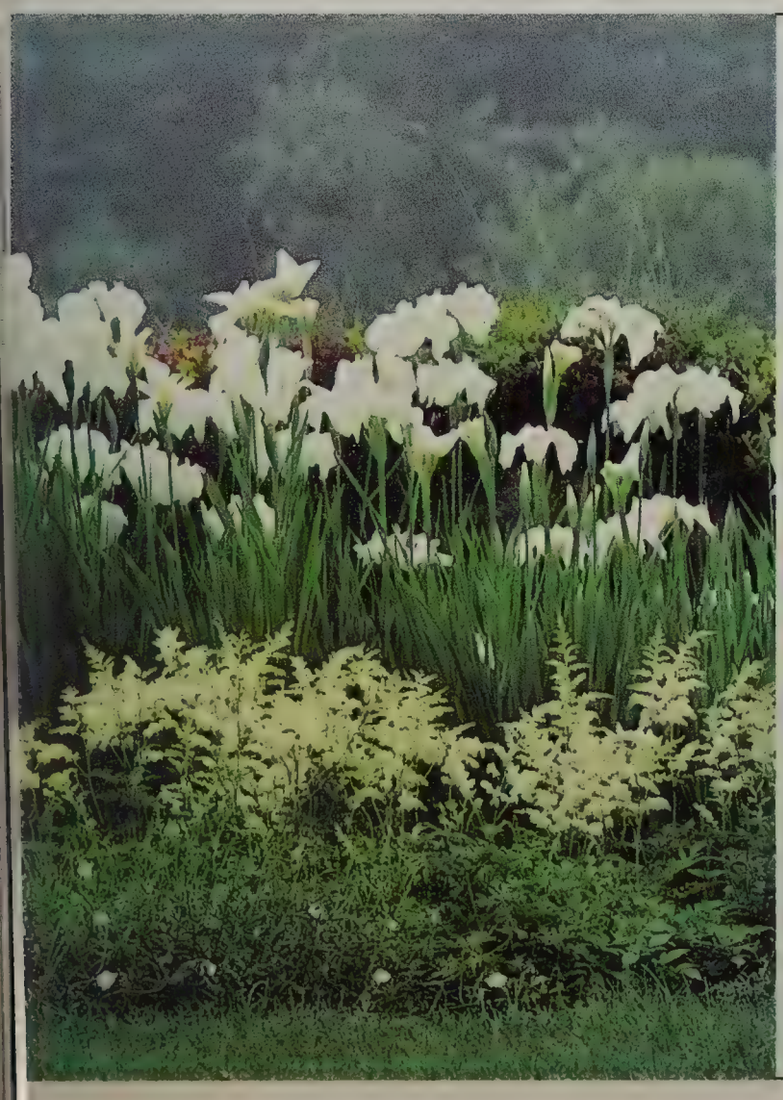
In such observational work on the behavior of animals in their natural habitat, one must pledge oneself to maximal noninterference. Passion taxed this principle to its absolute limit. Goodall told me that when Passion died "of an unknown wasting disease" in 1982, she (Jane, not Passion) watched with renewed faith in noninterference and some legitimate sense of moral retribution.

2. *Notornis,* the New Zealand ornithological journal, does not show up in the scientific equivalent of the corner drug store; I was therefore delighted when fellow columnist Jared Diamond alerted me (via *Nature,* which does appear at our watering holes) to a fascinating article by Michael Taborsky entitled "Kiwis and Dog Predation: Observations in Waitangi State Forest" (*Notornis,* vol. 35, pp. 197–202). The Waitangi Forest houses the largest "known and counted" population of the brown kiwi *Apteryx australis*—some 800 to 1,000 birds. In June and July of 1987, Taborsky and colleagues tagged twenty-four birds with radio transmitters "so that their spacing and reproductive activities could be studied" (all quotations come from Taborsky's paper cited above).

On August 24, they found a dead female, evidently killed by a dog. Thus began a tale worthy of *The Hound of the Baskervilles.* By September 27, thirteen of the tagged birds had been killed. All showed extensive bruising, and most had defeathered areas; ten of the thirteen birds "were found partly covered or completely buried under leaf litter and soil." Scientists and forestry workers found ten more carcasses without transmitters, all killed and buried in the same way, and all dispatched during the same period.

It didn't take the sleuthing genius of Mr. Holmes to recognize that a single dog had wreaked this reign of terror. Distinctive footprints of the same form appeared by the carcasses, along with "dog droppings of one type and size." On September 30, a female German shepherd, wearing a collar but unregistered, was shot in the forest. Her "long claws suggested that she had not been on hard surfaces for some time, i.e., was probably living in the forest." The killings abruptly stopped. Taborsky tagged several more birds with transmitters, bringing the total to eighteen; all these birds survived to the end of the study on October 31.

This Rin Tin Tin of the Dark Side had killed more than half of the tagged birds in six weeks. As "there is no reason to believe that birds with transmitters were at greater risk than those without," the total killed may range to 500 of the 800 to 1,000 birds in the population. Lest this seem a staggering and unbelievable estimate, Taborsky provides the following eminently reasonable defenses. First, given the remote chance of finding a buried, untagged kiwi carcass, the ten actually located during the interval of killing must represent the tiny pinnacle of a large iceberg. Second, other evidence supports a dramatic fall in total population: Ta-



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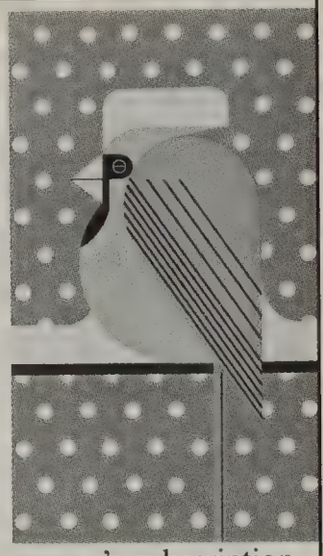

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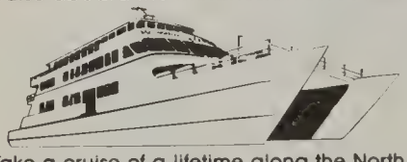

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borsky and colleagues noted a major drop in calling rates for these ordinarily noisy birds; a dog trained to find, but not to kill, kiwis could not locate a single live individual (although she found two carcasses) in a formerly well-inhabited section of the forest. Third, kiwis, having evolved without natural enemies and possessing no means of escape, could not be easier prey. Taborsky writes:

> Could a single dog really do so much damage? People working trained kiwi dogs at night know it is very easy indeed for a dog to spot and catch a kiwi. The birds are noisy when going through the bush and their smell is very strong and distinctive. When a kiwi calls, a dog can easily pick up the direction from more than 100 m away. With a kiwi density as high as it was in Waitangi Forest a dog could perhaps catch 10–15 kiwis a night, and the killing persisted for at least 6 weeks.

As to why a dog would kill so many animals "for sport," or at least not for food, who knows? We do, however, know enough to brand as romantic twaddle the common litany that "man alone kills for sport, other animals only for food or in defense." The kiwi marauder of New Zealand may have set a new record for intensity of destruction, but she followed the killing pattern of many animals. In any case, she surely illustrated the power of individuals to alter the history of entire populations. Taborsky estimates that given the extremely slow breeding of kiwis, "the population will probably need 10–20 years and a rigorous protection scheme to recover to previous densities."

These two stories may elicit both fascination and a *frisson,* but still strike some readers as unpersuasive regarding the role of individuals in science. To be sure, both Passion and the austral hell hound had disturbing effect on their populations. But science is general pattern, not ephemera perturbation. The Gombe chimps recovered in a few years, as a subsequent baboom offset Passion's depredations. On the crucial issue of scale, individuals still don't set patterns in the fullness of time or the largeness of space. Predictability under nature's laws takes over at an amplitude of scale and a degree of generality meriting the name "science." I would offer three rebuttals to this argument.

First, scale is a relative concept. What can put the boundary between perturbations in systems too small to matter and long-term patterns of appropriate generality? Human evolution is a tiny twig among millions on the tree of earthly evolution. But do all the generalities of anthropology therefore count only as details outside the more ample scope of true science? Earth

volution may be only one story of life among unknown cosmic billions; are all ne laws of biology therefore nothing but eculiarities of one insignificant example?

Second, small perturbations are not always reined in by laws of nature to bring systems back to a previous equilibrium. erturbations, starting as tiny fluctuations rought by individuals, can accumulate o profound and permanent alterations in much larger worlds. Much of the present ascination for chaos theory in mathematcs stems from its attempt to model such gents of pattern, even in large systems perating under deterministic laws. The Gombe chimps may feel no long-term effect of Passion's cannibalism, but the Waitangi kiwis may never recover.

Third, some natural populations may be so small that individuality dominates over pattern even if a larger system might fall under predictable law. If I am flipping a coin ten thousand times in a row, with nothing staked on any particular toss, then an individual flip neither has much effect in itself nor influences the final outcome to any marked degree. But if I am flipping one coin once to start a football game, then a great deal rides on the unpredictability of an individual event. Some important populations in nature are closer in number to the single toss than to the long sequence. Yet we cannot deny them entry into the domain of science.

Consider the large, orbiting objects of our solar system—nine planets and a few score moons. The domain of celestial mechanics has long been viewed as the primal realm of lawfulness and predictability in science—the bailiwick of Newton and Kepler, Copernicus and Galileo, inverse square laws and eclipses charted to the second. We used to view the objects themselves, planets and moons, in much the same light—as regular bodies formed under a few determining conditions. Know composition, size, distance from the sun, and most of the rest follows.

As I write this essay, *Voyager 2* has just left the vicinity of Neptune and ventured beyond the planetary realm of our solar system—its "grand tour" complete after twelve years and the most colossal Baedecker in history: Jupiter, Saturn, Uranus, and Neptune. Scientists in charge have issued quite appropriate statements of humility, centered upon the surprises conveyed by stunning photographs of outer planets and their moons. I admit to the enormous mystery surrounding so many puzzling features—the whirling storms of Neptune, when the closer and larger Uranus appears so featureless; the diverse and complex terrain of Uranus' innermost moon, Miranda. But I do

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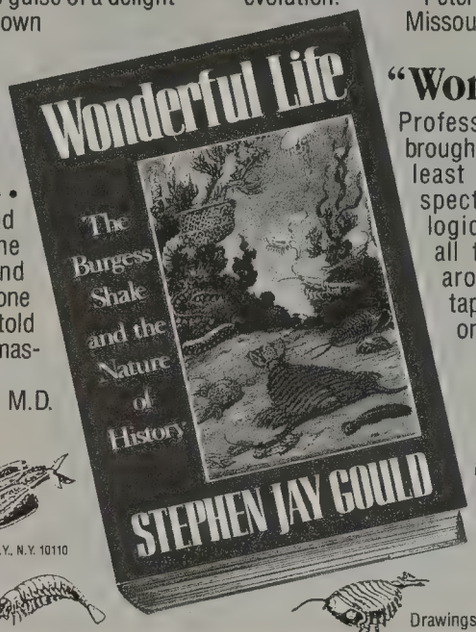

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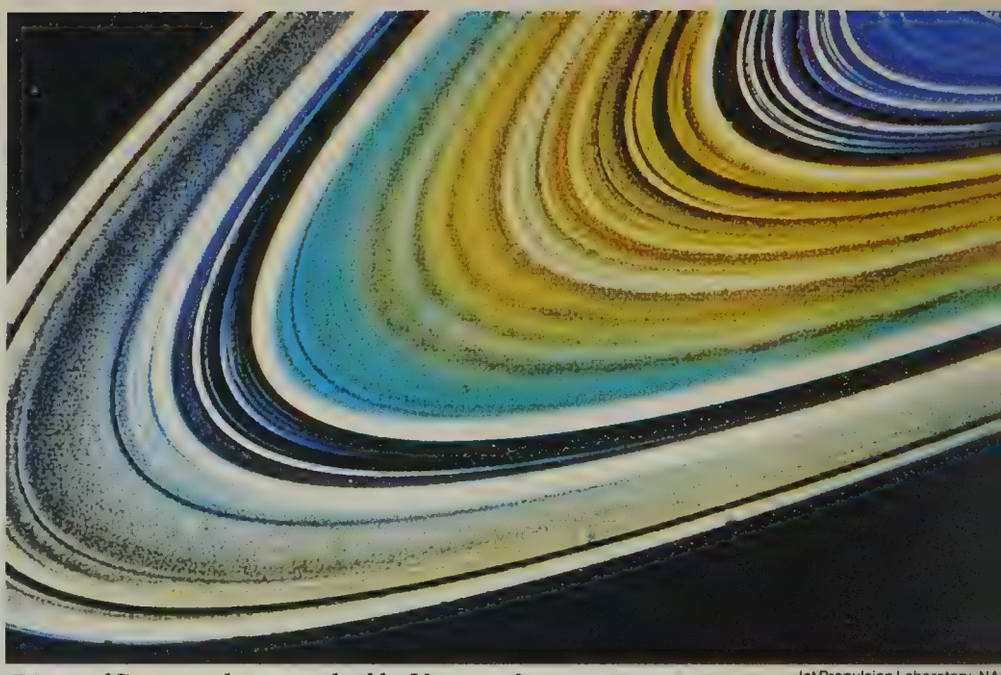

Rings of Saturn, photographed by Voyager 2

Jet Propulsion Laboratory, NA

think that a generality has emerged from this confusing jumble of diverse results, so many still defying interpretation—a unifying principle usually missed in public reports because it falls outside the scope of stereotypical science.

I offer, as the most important lesson from *Voyager,* the principle of individuality for moons and planets. This contention should elicit no call for despair or surrender of science to the domain of narrative. We anticipated greater regularity, but have learned that the surfaces of planets and moons cannot be predicted from a few general rules. To understand planetary surfaces, we must learn the particular history of each body as an individual object—the story of its collisions and catastrophes, more than its steady accumulations; in other words, its unpredictable single jolts more than its daily operations under nature's laws.

While *Voyager* recedes ever farther on its arc to the stars, we have made a conceptual full circle. When we launched *Voyager* in 1977, we mounted a copper disk on its side, with a stylus, cartridge, and instructions for playing. On this first celestial record, we placed the diversity of the earth's people. We sent greetings in fifty-five languages, and even added some whale song for ecumenical breadth. This babble of individuality was supposed to encounter, at least within our solar system, a regular set of worlds shaped by a few predictable forces. But the planets and moons have now spoken back to *Voyager* with all the riotous diversity of that unplayed record. The solar system is a domain of individuality in my third argument for small populations composed of distinctive objects. And science—that wonderfully diverse enterprise with meth ods attuned to resolve both the lawful mi lions and the unitary movers and shak ers—has been made all the richer.

This is my third and last column o *Voyager*. The first, which shall be my ete nal incubus, praised the limited and law ful regularity that *Voyager* would presum ably discover on planetary surface throughout the solar system. I argued, fo lowing the standard "line" at the time (bu bowing to convention is never a good ex cuse), that simple rules of size and compo sition would set planetary surfaces. Wit sufficient density of rocky composition size alone should reign. Small bodies, wit their high ratios of surface to volume, ar cold and dead—having lost so much inte nal heat through their relatively large su face and being too small to hold an atmo sphere. Hence, they experience n internal forces of volcanism and plate tec tonics and no external forces of atmo spheric erosion. In consequence, sma planets and moons should be pristin worlds studded with ancient impact cra ters neither eroded nor recycled durin billions of years. Large bodies, on th other hand, maintain atmospheres and in ternal heat machines. Their early crater should be obliterated, and their surfaces like our earth's, should bear the marks o continuous, gentler action.

The first data from planetary probe followed these expectations splendidly Small Mercury and smaller Phobus an Deimos (the moons of Mars) are intensel cratered, while Mars, at its intermediar size, showed a lovely mixture of ancien craters and regions more recently shape by erosion and volcanic action. But the *Voyager* reached Jupiter and the story

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started to unravel in favor of individuality granted by distinctive histories for each object.

Io, Jupiter's innermost major moon, should have been dead and cratered at its size, but *Voyager* spotted large volcanoes spewing forth plumes of sulfur instead. Saturn's amazingly complex rings told a story of repeated collisions and dismemberments. Miranda, innermost moon of Uranus, delivered the *coup de grâce* to a dying theory. Miranda should be yet another placid body, taking its lumps in the form of craters and wearing the scars forever. Instead, *Voyager* photographed more signs of varied activity than any other body had displayed—a geological potpourri of features, suggesting that Miranda had been broken apart and reaggregated, perhaps more than once. Brave new world indeed.

I threw in the towel and wrote my second column in the *mea culpa* mode (June 1986). Now I cement my conversion. *Voyager* has just passed Neptune, last post of the grand tour, and fired a glorious parting shot for individuality. We knew that Triton, Neptune's largest moon, was odd in one important sense. All other bodies, planets around the sun and moons around the planets, revolve in the same direction—counterclockwise as you look down upon the plane of the solar system from above. But Triton moves around Neptune in a clockwise direction. Still, at a size smaller than our moon, it should have been another of those dead and cratered worlds now mocked by the actual diversity of our solar system. Triton—and what a finale—is, if anything, even more diverse, active, and interesting than Miranda. *Voyager* photographed some craters, but also a complexly cracked and crumpled surface and, most unexpectedly of all, volcanoes, probably spewing forth nitrogen in streaks over the surface of Triton.

In short, too few bodies, too many possible histories. The planets and moons are not a repetitive suite, formed under a few simple laws of nature. They are individual bodies with complex histories. And their major features are set by unique events—mostly catastrophic—that shape their surfaces as Passion decimated the Gombe chimps or the austral hound wreaked havoc on the kiwis of Waitangi. Planets are like organisms, not water molecules; they have irreducible personalities built by history. They are objects in the domain of a grand science—natural history—that provided this magazine its name.

Because *Voyager* has increased our knowledge, and at least for this paleontologist, integrated his two childhood loves of astronomy and fossils on the common ground of natural history, I cannot let this primary scientific triumph of our generation pass from our solar system (and these columns) without an additional comment in parting.

Knowledge and wonder are the dyad of our worthy lives as intellectual beings. *Voyager* did wonders for our knowledge, but it performed just as mightily in the service of wonder—and the two elements are complementary, not independent or opposed. The thought fills me with awe—a mechanical contraption that could fit in the back of a pickup truck, traveling through space for twelve years, dodging around four giant bodies and their associated moons, and finally sending exquisite photos across more than four light-hours of space from the farthest planet in our solar system. (Pluto, although usually beyond Neptune, rides a highly eccentric orbit about the sun. It is now, and will be until 1999, within the orbit of Neptune and will not regain its status as outermost until the millennium. The point may seem a bit forced, but symbols matter and Neptune is now most distant. Moments and individualities count.)

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Neptune with Triton in the background

Jet Propulsion Laboratory, NASA

The photos fill me with joy for their ierce beauty. To see the most distant noon with the detailed clarity of an object hot at ten palpable paces; the abstract wirling colors in Jupiter's great spot; the uminosity and order of Saturn's rings; the giant ripple-crater of Callisto, the cracks of Ganymede, the sulfur basins of Io, the craters of Mimas, the volcanoes of Triton. As *Voyager* passed Neptune, her programmers made a courtly and proper bow o aesthetics and took the most gorgeous picture of all, for beauty's sake—a photograph of Neptune as a large vertical crescent, with Triton as a smaller horizontal crescent at its side. Two perpendicular horns, proudly independent but locked in a common system. Future advertisers and poster makers may turn this exquisite object into a commercial cliché, but let it stand for now as a symbol for the fusion of knowledge and wonder.

Voyager has also served us well in literary allusions. Miranda is truly the "brave new world" of her most famous line. And Triton conjures all the glory and meaning of his most celebrated reference. You may have suppressed it, for forced memorization was a chore, but "The World Is Too Much with Us" remains a great poem (still assigned, I trust, by teachers). No one has ever matched Wordsworth in describing the wonder of childhood's enthusiasms—a wonder that we must strive to maintain through life's diminution of splendor in the grass and glory in the flower, for we are lost eternally when this light dies. So get to know Triton in his planetary form, but also remember him as Wordsworth's invocation to perpetual wonder:

> . . . Great God! I'd rather be
> A Pagan suckled in a creed outworn;
> So might I, standing on this pleasant lea,
> Have glimpses that would make me
> less forlorn;
> Have sight of Proteus rising from the sea;
> Or hear old Triton blow his wreathed horn.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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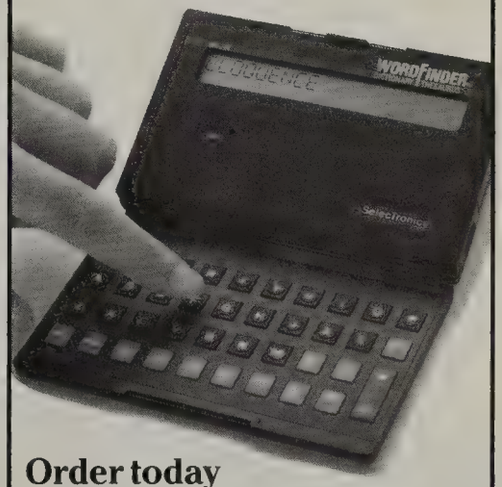

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An adult gentoo penguin wades calmly ashore. Like chinstraps and Adélies, gentoos are vulnerable to leopard seals and other predators but are typically less wary and nervous.

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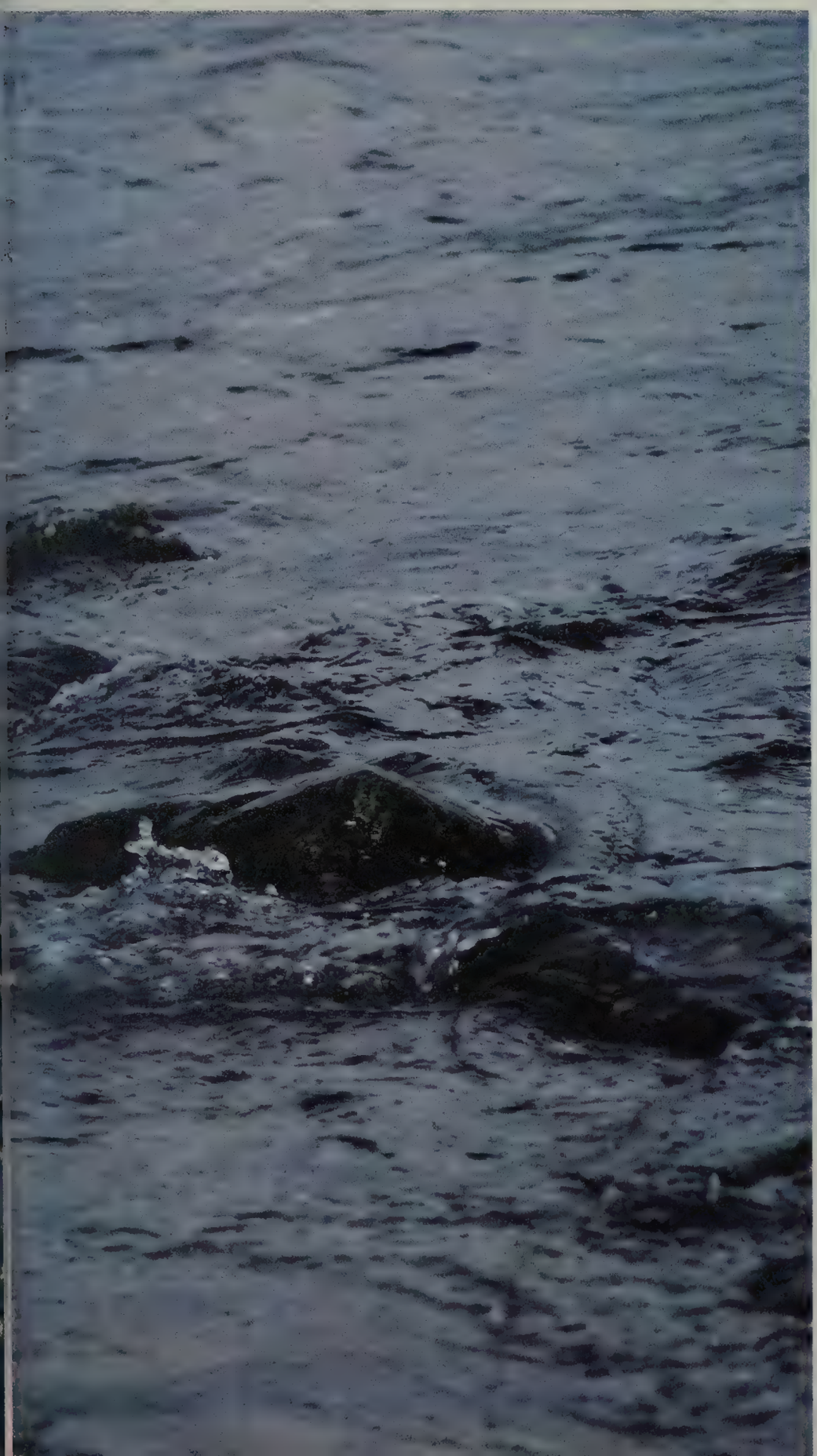
Antarctica's Well-bred Penguins

When three species overlap, good eating habits make good neighbors. It also helps to hold your breath longer than the other guy

by Susan G. Trivelpiece and Wayne Z. Trivelpiece



September in the Antarctic Peninsula. Spring is just around the corner. Several gentoo penguins stroll on the beach or paddle in the surf, coming and going as they please, to hunt for food or bathe. Although the wind still howls at more than thirty miles per hour and snow and ice predominate, the winter has been relatively mild, and the waters of Admiralty Bay off nearby King George Island have been mostly ice free all season. Most of the adult gentoos have survived the May-to-August winter, in stark contrast to other years when heavy pack ice forced the gentoos to leave in search of open water.

As September draws to a close, a lone Adélie penguin bounds out of the icy waters and onto the cobble-rock shore of Admiralty Bay. He preens briefly, then toboggans on his breast past several oblivious gentoos toward a distant, windswept hilltop. The winds gust over the island's glacial cap, creating blinding whiteouts, but the Adélie continues undaunted. At the hill's crest, he moves unerringly to the exact location of last year's nest and begins to pry pebbles from the frozen ground. Within days, thousands of other Adélies will arrive from their wintering grounds on the pack ice to begin again the cycle of life on these barren shores.

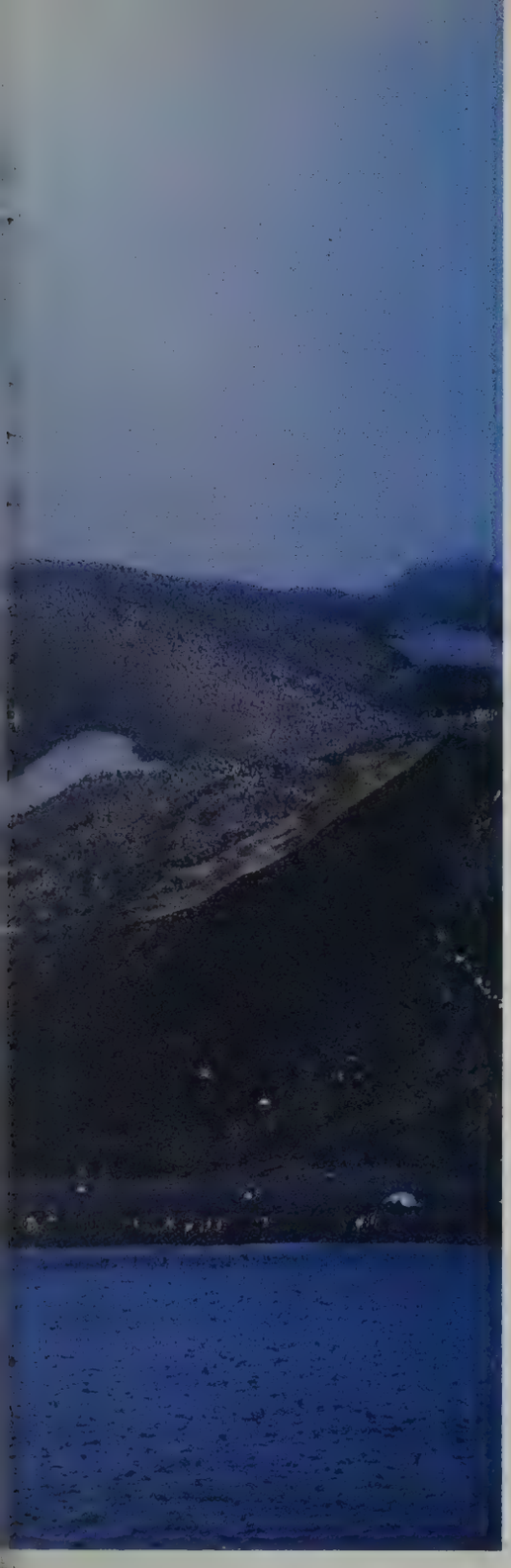
Almost a month has passed. The wind continues to blow relentlessly, and deep, frozen snowdrifts remain in all except the most windswept areas. But there's a warm breath in the chill air, and the daylight hours are lengthening. All of the Adélies are incubating eggs, and some of the gentoos are beginning to lay, when a third species of penguin arrives. Slowly, chinstrap penguins dribble in from their wintering area in the open seas to the north and take up residence at their previous year's nest sites, typically on ledges in steeper terrain than that used by the other species. With the arrival of the chinstrap, the antarctic breeding season is in full swing, and the air reverberates with the raucous trumpeting, braying, whining, and hissing of thousands of penguins.

For eleven of the last thirteen years, we have been undertaking a migration of our own, from the Point Reyes Bird Observatory in California to a small field hut on

Copacabana Beach on King George Island. About forty miles long and fifteen miles wide, it is the largest of the South Shetland Islands off the Antarctic Peninsula. With funding from the National Science Foundation, we have been studying the breeding biology and feeding ecology of these three species, all members of the same genus (*Pygoscelis*). Our goal has been to better understand how closely related populations living near one another divvy up available resources.

Throughout most of the Antarctic, these three penguin species have separate breeding ranges. Most Adélies concentrate around the far southern perimeter of the Antarctic continent: for them, the Antarctic Peninsula is the northern breeding limit. The gentoos' distribution is more moderate in latitude, 50° to 65° south, in the scattered subantarctic island groups; the Antarctic Peninsula represents the southernmost extent of their breeding range. Chinstraps, however, can truly call the peninsula "home," for the breeding distribution of this species is centered in the Scotia Sea along the Antarctic Peninsula. And it is only on the islands off the peninsula that the three species can be found together. All three breed on "our" island, King George, a stark and beautiful land of ice fields and glaciers interspersed with outcrops of lichen-covered rocks, barren hilltops, and stretches of cobble beaches. During the austral summer (November to February), the shores near our hut teem with animal life, including skuas, gulls, petrels, and some species of seals, but mostly—as is true of so much of coastal Antarctica—penguins.

Antarctica may be, by some reckonings, the most inhospitable piece of real estate on earth, but penguins flourish along its shores, often inhabiting rookeries by the hundreds of thousands. Fossil evidence indicates that penguins evolved from flying ancestors at least forty million years ago. Several unique adaptations allow them to exploit Antarctica's rich marine environment. Paddlelike flippers and streamlined bodies enable them to "fly" underwater; densely packed, hairlike feathers and a thick layer of fat protect them from the subfreezing seawater tem-



Hundreds of thousands of chinstrap penguins breed at Bailey Head on Deception Island.
Laura Riley

Map and diagrams by Joe LeMonnier

peratures; and solid bones replace the hollow ones typical of most birds, greatly enhancing their diving ability.

These adaptations allow the penguins to thrive under conditions where most animals would perish. And of all penguin species, Adélies and chinstraps are perhaps the most abundant, numbering an estimated 50 to 100 million each, while gentoos are an order of magnitude less plentiful at 5 to 10 million. Penguin numbers have not always been so high, reaching current levels only after the massive harpooning of the large baleen whales in the late 1940s to 1960s. The key to their increase may be krill, small shrimplike crustaceans, up to sixty millimeters long, that abound in antarctic waters during the summer. A consumer of microscopic plant life at the base of the marine food web, krill are usually found in highly concentrated swarms. A primary food for many whales, seals, and birds, they are the most important members of the antarctic zooplankton community. Adélies and chinstraps eat krill almost exclusively, while the gentoos' diet is about 85 percent krill and 15 percent fish. Simply put, fewer whales meant more food for penguins.

When our study began, our first hypotheses were shaped, not surprisingly, by what was already known about the three penguin species. Adélies were by far the best known, largely from earlier work by David Ainley (also from Point Reyes) and his co-workers. The Adélies' annual cycle includes eight months (February through September) spent on the pack ice, a vast ring of frozen sea that surrounds the icy continent each winter. As the ice begins to break up with the September advent of spring, Adélies migrate to their breeding grounds. Males arrive first to claim and defend a nest site and advertise for mates with raucous, staccato "ecstatic" calls emitted with flippers waving and bills pointed skyward. Females appear several days later, and a pair bond is soon formed, followed by copulations, pebble gathering, and nest building. After two to three weeks, the female lays two eggs in the little pile of pebbles that serves as a nest. She then goes to sea almost immediately, leaving the male to incubate. This first incubation shift averages two weeks, and by its end, the male will have fasted for at least five weeks. After being relieved by the female, the male goes to sea to feed for about ten days. After this first round, incubation shifts get shorter and shorter, until at the time of chick hatching (thirty-two to thirty-five days after egg laying), males and females switch every twenty-four hours. In this way, the adults regain much of their energy and are ready to feed chicks on a daily basis.

Newly hatched chicks are totally dependent on their parents for the first three weeks. One adult remains at the nest, providing warmth and protection for the

Two chinstrap chicks, about one week old, will be fed by their parents for six more weeks. After that, they will be entirely on their own.
Laura Riley

chicks, while the other goes to sea to find food for the young. The parents switch these duties daily. An adult returning from a foraging trip goes to the area of its nest and gives the so-called loud-mutual call, an individually specific vocalization; the answer by its mate assures the bird it has found the right nest. Adélies depend upon this vocalization to recognize one another; it is typically the only way an individual can find its nest amidst thousands of others. The chicks learn to recognize their parents' call and soon associate it with food. They react to the calls by begging; the adult delivers the food, predominantly krill, by regurgitation.

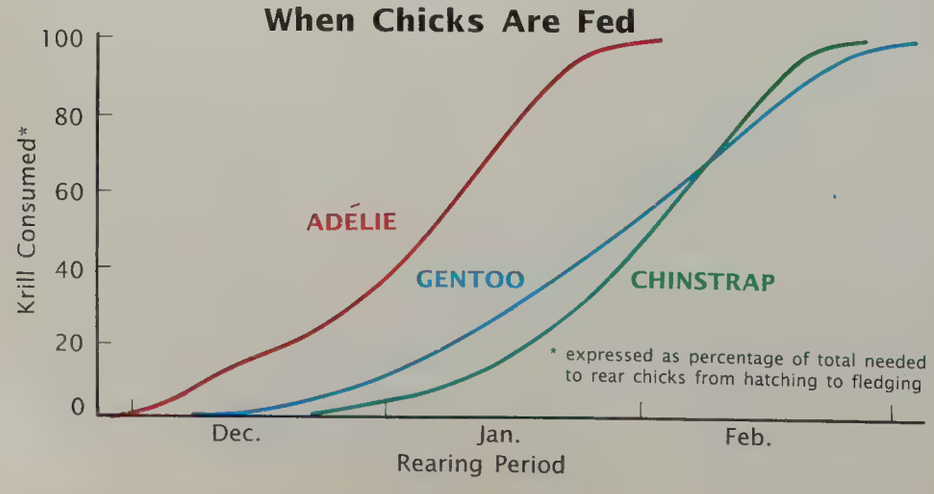
After three weeks, the chicks need more food per day than one parent can provide, so they are left alone while both parents go to sea to forage. The chicks have developed a thicker coat of down by this time and can thermoregulate on their own, relieving the parents of brooding responsibilities. With fewer adults around, the chicks gather together into loose groups, or crèches, primarily as a defense against the brown skua, a large, gull-like bird that nests near the penguin colonies and eagerly swoops up any unattended eggs or stray chicks.

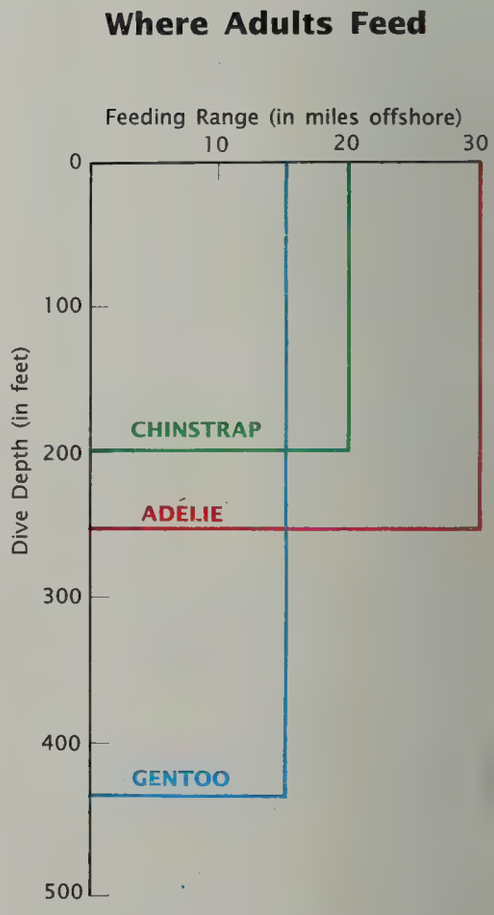
When an adult returns from the sea, it proceeds to the vicinity of its nest, which by now has disappeared under several inches of pink guano, and announces its arrival by giving the same loud-mutual call it used earlier to locate its mate. The chick, often yards away, recognizes its parent's call and responds with an almost frantic eagerness, begging for food. Often several unrelated chicks will also react to the call of a returning adult, presumably in hopes of getting a free meal. Determining which are the right chicks to feed is not easy, since the adults cannot recognize their offspring by sight or call. The parents often resort to what has been termed the feeding chase: the besieged adult turns tail and flees the hungry horde, forcing the chicks to race after it. Such a chase involves burning up important energy reserves, and it has been demonstrated that only those chicks sure of a meal (the true chicks of that adult) make the effort.

Chicks gain weight rapidly, going from hatching weights of about 2.5 ounces to fledging weights of about 7.5 pounds just seven weeks later. At fledging, the parents abandon their chicks and go to sea to feed, in preparation for their upcoming molt, which occurs elsewhere, probably on land or pack ice in the vicinity of their wintering grounds. The young Adélies then enter the sea and migrate to the pack ice, where they stay for two to five years before returning to breed at the rookery of their birth. Most of these chicks will never return, however. Our data on chick survival suggest that only 10 to 15 percent of the fledging chicks will survive this rite of passage from shore to sea, where they must learn how to find and capture their own food, while avoiding their main predator, the leopard seal.

The chinstrap penguin's breeding season is much like the Adélie's—with some important differences. Chinstraps arrive a month later, the first incubation shift is usually taken by the female (not the male, as is always the case with Adélies), and is closer to one week than two. Once the chicks hatch, they are fed on the average every sixteen to eighteen hours (compared with twenty-four hours for Adélies). Chicks may also be slightly older and heavier than Adélies at fledging, and unlike Adélies, survivors begin returning to their natal rookery the very next year. However, as with Adélies, they will not breed until at least three years of age.

The nonmigratory gentoo penguins are distinctly different from their congeners, in both behavior and life-history strategies. With the advent of the breeding season, the pairs begin to construct nests, often in several different areas. Instead of a long fasting period prior to egg laying, like the Adélies and chinstraps, both pair members forage at sea during the day and return to the nest at night to display and court. Five or so days before egg laying, however, the female remains at the nest, while the male continues his daily forag-



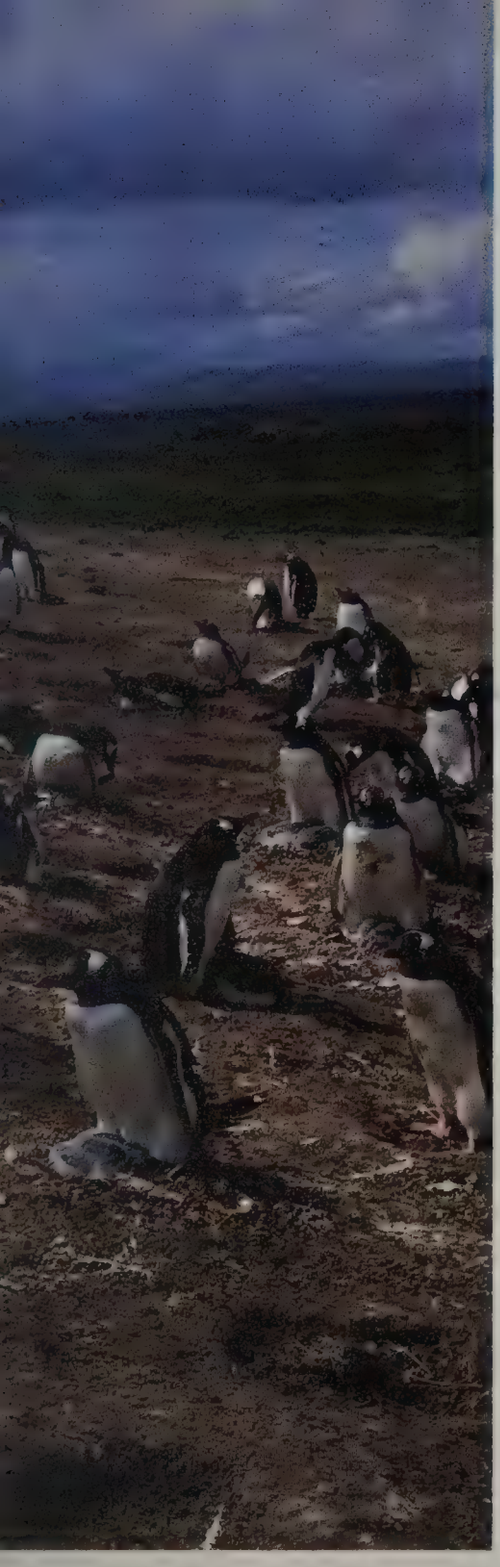


ing trips. After this short fast, the female lays her two eggs, about two weeks later than Adélies and two weeks earlier than chinstraps. Males and females exchange nest duties daily throughout incubation and then at twelve-hour intervals after the chicks hatch. Nest reliefs involve a recognition call that sounds much like a donkey's bray. However, unlike Adélies and chinstraps, gentoos also appear able to recognize each other by sight, often with the bird on the nest "braying" to its silently aproaching mate. For the first three weeks, parents continue to take turns guarding the chicks; after that, they leave them unattended, and the chicks form crèches. The young penguins begin to go to sea on their own at about eight weeks of age but return to the beach every evening to be fed by an incoming parent. In this way, they learn how to forage gradually, while being supplemented along the way. Gentoo chicks become fully independent in March or April, between their tenth and fifteenth week, when their parents come ashore for their three-week molt and can no longer provide any food. Juveniles disperse during their first winter to unknown locations, returning to their natal rookeries the following summer but not attempting to breed until two years of age.

How does each species exploit its own part of the Antarctic Peninsula's ecological resources? We looked at differences among the penguins for clues. Adélie males, for example, are strongly attached to a nest site but prone to changing mates from year to year. Gentoos have a far stronger pair bond, but the pair frequently change location. They alone will double brood if they lose their first clutch of eggs, usually choosing a new site for the second nesting attempt. Chinstraps are the only ones with strong attachments to both their nest sites and mates.

These three distinct patterns probably represent adaptations to the environmental conditions each species encounters in the heart of its breeding range. For the Adélie and the gentoo, this "heart" occurs south and north, respectively, of the Antarctic Peninsula. Adélies breeding in the far south are faced with a scarcity of suitable breeding sites and a short season.

Erwin & Peggy Bauer



Unlike Adélies and chinstraps, adult gentoos, left, are able to pick out their mates in a crowded colony by sight, as well as sound. Young gentoos continue to receive supplemental food from their parents for a couple of weeks after fledging. The chick below, about to receive a regurgitated meal from its parent, has about six weeks left before fledging.

Frans Lanting; Minden Pictures

Males cannot afford to wait for a tardy mate but must begin the nesting cycle quickly in order to fledge chicks before the summer ends. Gentoos, in contrast, generally find breeding sites plentiful throughout most of their subantarctic breeding range, so attachment to a given site is unnecessary. In addition, their breeding season is longer, and since these birds are nonmigratory, pairs are together year-round, the advantages of breeding with mates of known quality perhaps favoring strong bonds.

Only for the chinstrap is the Antarctic Peninsula the norm. This species' strong nest-site bonds may be a product of the region's highly variable conditions, which range from warm and snow free to ice-bound and heavily snow covered. Hanging on to a nest site reliably swept free of snow by the spring winds provides the same advantage to chinstraps as to Adélies. But unlike the Adélies—adapted to the very short austral summer farther south—chinstraps enjoy a relatively prolonged, five- to six-month summer season. The males can afford to wait to start a nest if this in turn allows them to re-pair with the female of the previous year.

Adélie, gentoo, chinstrap—each goes about the business of breeding somewhat differently, but the results are roughly the same. All lay two-egg clutches and have fledged an average of one chick per pair throughout the eleven years of our study. In any given year, one species may do significantly better, but overall, the three have similar rates of productivity.

As a comparison of the species' breeding schedules would suggest, timing is a key factor. The staggered breeding times—Adélies breeding two weeks before gentoos, which breed two weeks before chinstraps—reduce heavy competition for krill during the demanding chick-rearing periods. The early breeding Adélie penguins have fledged their chicks by the time the later breeding gentoos and chinstraps start requiring large amounts of food for their broods.

How far a bird ranges from its breeding ground to forage can also segregate it ecologically from its neighbors. But how to figure out where a penguin is going when it "flies off"? One clue lay in the birds' nest-relief intervals during the chick-feeding phase, which we knew were constant from year to year: twelve hours for gentoos, sixteen to eighteen hours for chinstraps, and twenty-four hours for Adélies. Using these intervals and the penguins' known swimming speeds, we predicted that gentoos must forage largely within Admiralty Bay, that chinstraps can range up to twenty miles into the Bransfield Strait, and that Adélies have a potential feeding range of thirty miles. This is not to say that the penguins deliberately choose different feeding areas. Adélies, for instance, do not pass up krill swarms that they encounter inshore, but with their longer relief time, they do have the greatest potential search area.

To follow penguins throughout complete foraging trips and time the feeding dives of each species, we glued tiny transmitters to the back feathers of adult penguins with two- to three-week-old chicks. Then we tracked them at sea by triangulation from two receiver stations on hills above Admiralty Bay. We coupled one receiver to a continuously running strip-

As an Adélie chick, below, loses its brown down, its juvenile plumage begins to emerge. It will acquire the black-chinned uniform of a mature Adélie only after its first year at sea. Right: Swimming penguins have several modes of locomotion: they can paddle along much like ducks, porpoise in and out of the water, or "fly" beneath the surface.

Both photographs by Frans Lanting; Minden Pictures

chart recorder that gave us a visual printout of how much time a penguin spent at the surface or diving during a foraging trip. We also recorded how far they moved between dives. By analyzing distinctive patterns on the printouts, we could distinguish among dives that represented traveling to the foraging areas, searching for krill, and actual feeding. We now had a way of following known breeding penguins and determining how they partitioned their time at sea.

These data helped resolve another mystery uncovered by our studies: How is it possible that gentoo penguins bring food to their chicks more frequently than their congeners and do so from the smallest potential foraging area? We knew, from data collected by Polish investigators at nearby Arctowski Station, that krill swarms are found at varying depths in Admiralty Bay and the Bransfield Strait, from the surface to as deep as 450 feet. Other researchers have recently shown that gentoos dive deeper than their congeners, reaching maximum depths of more than 400 feet, compared with a maximum of 200 to 250 feet for chinstraps and Adélies. We found that gentoos also make significantly longer feeding dives—120 seconds compared with the chinstraps' 91. As superior divers, foraging gentoos have the capacity to feed on deeper swarms of krill and spend a greater part of any given dive catching prey. Thus, gentoos can exploit most krill swarms they locate, while chinstraps and Adélies may have to spend more time traveling in search of food.

By this route, our inquiry arrived at several of the main factors segregating the penguins' ecological niches. Although all three species largely depend on the same food resource during austral summers in the Antarctic Peninsula area, gentoos are able to coexist with the more numerous Adélies and chinstraps by exploiting a deeper, inshore feeding niche, and competition between the Adélie and chinstrap populations is reduced by the full one-month difference in the timing of their breeding cycles. While the three species' breeding strategies are a result of adaptations to conditions at the center of their respective breeding ranges, the resultant differences allow them to coexist where their breeding ranges do overlap.

Our years with the penguins have taught us a great deal about their dependence on krill. Increasingly, the penguins are not the only two-footed animals interested in the tiny crustaceans: a new and growing commercial krill harvest has become one of the many pressures bearing on Antarctica's great natural resources. Penguins, because of their prominence in the food chain and their reliance on krill, are now under study at several sites around Antarctica. The goal of this internationally coordinated effort is to establish base-line information on several aspects of penguin biology that are likely to be sensitive to human-induced reductions in krill stocks. If penguins begin to show signs of a food shortage, that will be a strong indication that something is amiss with the krill fishery, which by treaty must be managed so that other dependent species, such as penguins, seals, and whales, are not adversely affected by fishery activities. Our work has thus taken on a new twist, and our hope now is that in the years to come, it may contribute toward insuring that humans will not deplete this astoundingly rich, but not infinite, food supply on which so many of the earth's creatures depend. □

A glossy bank vole feeds on a blackberry
Barrie E. Watts; Oxford Scientific Films

The Lemming Phenomenon

Or why the legendary mass migrations of rodents are restricted to the extreme north

by Lennart Hansson

As a young man more than half a century ago, British ecologist Charles Elton visited Norway while en route to the Spitsbergen archipelago (Svalbard) in the High Arctic. His visit happened to come during a year when lemming populations were at a peak, and Elton witnessed great numbers of these small, black-and-yellow rodents streaming down mountainsides into the coniferous forests below. He was told that the following year there would be hardly any lemmings, but that a few years later, another spectacular lemming migration would occur. Elton was also told that other species of small rodents, such as voles and mice, went through similar ups and downs at the same times.

When he returned to England, Elton was eager to pursue his new interest in small mammals and soon found a place near Oxford where voles were abundant. He studied the voles closely for many years and decided the little English rodents were behaving much like those he had observed in Norway. He used the term *cycles* to describe the rapid appearance of large numbers of rodents, the quick decline, or crash, that followed, and then the new peak two or three years later. Elton assumed that such great and regular variations in rodent populations were common. The causes of cycles, however, proved difficult to determine, and the problem eventually attracted many scientists all over the world. I was one of them, although little did I know as I began my work how seldom I would witness the sort of cycle so dramatically described by Elton and others.

I began my field studies in the southernmost part of Sweden in the midsixties. The warm water carried north by the Gulf Stream brings mild and humid weather to this part of the country, as it does to all the northwestern coast of Europe. Southern Sweden, for example, generally experiences only a few weeks of shallow snow cover each year, despite its relatively high latitude (56° north). I started with all-year trapping on small parcels of abandoned croplands and in forests. The forests here are mainly deciduous, with beech and oak the most common trees. No lemmings live in southern Sweden, but I had no trouble trapping several of the other rodent species in the area. The field mice I caught, however, proved so fast and hard to handle that I soon focused my attention on two other, more manageable local rodents: bank voles, which live in dense forests; and field voles, which inhabit fields, clear-cuttings, and dense grass in recently reforested areas.

The reproductive potential of these rodents is enormous. Becoming sexually receptive in April and bearing their first young of the year in mid-May, females can produce five or six young every twenty-five days or so up until the end of September. Furthermore, any female born by midsummer may have a few litters of her own during late summer or early autumn. Mortality is high, of course, and in reality, very few females have more than three litters before they wind up as a meal for a predator. The mean life span of these voles is about three or four months.

I have now been studying small rodents in southern Sweden for more than twenty years but have never found the dramatic several-year cycles described by Elton and his students. Instead, all species have shown a regular annual pattern of very low spring densities and high autumn densities. Their numbers do rise during the breeding season, with autumn totals often five to ten times those of the spring. Some years have had higher autumn peaks than others, but the differences have not been great. Therefore, much of my thinking has been devoted to learning why "my" rodents don't go through population cycles and whether they can help us understand the dynamics of rodents that do. Inevitably, this has involved delving into the history of rodent-cycle research.

The first round of work, from 1925 to 1930, led Charles Elton to consider parasites or disease as the most likely cause of cycles, perhaps after hearing from some Norwegians that both people and lemmings tend to get sick at times of rodent population crashes. But although Elton and his students surveyed many small rodent populations in Great Britain for tuberculosis, toxoplasmosis, and a number of other diseases, they were unable to demonstrate any clear relationship between disease and rodent numbers. Then World War II broke out, interrupting this work and, as it turned out, largely bringing it to an end.

After the war, researchers again began to study rodent cycles, but this time the emphasis was placed on the animals' social behavior. One school of thought, developed in the United States, held that external physical and social factors acted together to stress the animals and upset their hormonal systems. Human physiological responses to stress had first been observed in detail in concentration camp prisoners. These studies showed that the body's first response to stress is physiological arousal and mobilization of adrenal hormones, followed by intensive use of the body's glycogen and sugar reserves and, finally, by exhaustion and, possibly, death. Based on these findings, the American theory posited that when rodent populations reached a certain degree of density, the animals were under such stress that

they exhausted their bodily resources and eventually died of hypoglycemia. Aggression, often noted in migrating lemmings and in laboratory rodents that were crowded into cages, was considered first to be one factor and then later to be the main factor in triggering the physiological mechanism that could bring about nearly simultaneous death in many animals. This idea had serious shortcomings, however, one of them being that natural populations continued to decline after passing levels at which density previously permitted population growth.

In the late fifties, Dennis Chitty, who had worked with Elton before the war, proposed that two types (or morphs) of voles lived in every population: one was small and timid, but prolific; the other, large and aggressive, but less fecund. Differences between the two were assumed to be genetic, and population increases and crashes were presumed to result from natural selection acting differentially on them. The idea was that the timid morph was favored at low population levels, and the aggressive one at high densities. Chitty went to the University of British Columbia in Vancouver, which became the center of forceful attempts to test this proposition. The Chitty hypothesis was soon popular all over North America, Britain, and even in the Soviet Union. I found, however, that it couldn't explain the existence of relatively stable populations such as those I studied in southern Sweden.

After some years, I started to work with small rodents in northern Sweden, and to some extent in northern Norway and Finland as well. The climate there is very different from that farther south. The Gulf Stream still drives in humid clouds from the Atlantic, but cold air blown in from continental Russia and Siberia produces very harsh winters. Snowfall is heavy; in many places the snow cover exceeds three feet and lasts seven or eight months. The vast forests are coniferous, with dwarf shrub heaths above timberline. Agricultural land is almost absent. In this environment, I finally saw what Elton had seen some forty years earlier: thousands of Norway lemmings running downhill from the alpine heaths one autumn and no lemmings at all the next. But one other discovery was still more exciting to me. Bank and field voles, the same species I had come to know so well in the south, appeared in enormous numbers at the same time as the lemmings. The next spring, the ground was covered with vole runways, formed in winter in the space between the snow and the vegetation. Many nests, built by field voles in this space, were also exposed after the thaw. But the voles themselves, like the lemmings, were gone.

In the years that followed, I studied the northern voles throughout their cycle. I found that as populations were on the increase, the small rodents reproduced intensively, even in winter. As soon as the population hit peak density, however, females born the previous year usually produced only one litter and those born within the year produced none. The largest litters were produced when the population was increasing, and individual animals tende to be largest just as the population wa approaching its peak size.

The small rodent populations of north ern and southern Sweden were obviousl very different. But what about the rest c Scandinavia and western Europe, includ ing Elton's England? I asked Heikk Henttonen of the University of Helsinki t join me in analyzing relevant small-roden studies. We started with Scandinavia where clear differences between sout and north emerged. Below 59° north lat tude, almost all studies revealed the sort c annual pattern—spring lows, autum highs—I had found in southern Sweden North of 61°, nearly all were of the mor dramatic multiyear, or cyclic, type. Be tween 59° and 61° was a transition zon with varying dynamics. The only norther populations with annual shifts were foun on islands off the northwest coast of Nor

In northern Scandinavia, many predators, such as the great gray owl, left, depend heavily on a diet of small rodents. Below: When not participating in the spectacular mass movements for which the species is famous, the Norway lemming is generally solitary.

Gustav Hansson; Bildhuset

way and more or less inside the Gulf Stream.

When we turned our attention to western and central Europe, we found generally the same annual fluctuations as in southern Scandinavia. Data from the Soviet Union showed more variations between years but not as pronounced as in northern Scandinavia. All in all, to our surprise we found few pronounced, naturally occurring cycles anywhere outside of northern Scandinavia. And, significantly perhaps, the exceptions seemed characterized by some specific disturbance in the ecosystem: in England, for example, plantations of forests on former grazing ground. There was even evidence that rodent populations in these areas became more stable as such forests grew up. Could Elton have come across such a wildly fluctuating population after his return from Norway, assumed it was a nearly universal phenomenon, and thus affected the whole history of small-rodent research?

At first the information from North America especially confused us. There we found many cases of annual variations and a number of multiyear cycles (the latter often on abandoned fields) but no significant or consistent geographical gradient. This was disconcerting, since latitudinal changes in such things as climate and vegetation are similar in North America and Europe. We sat for several days with our data, discussing why the situation might be so different on the two continents. Finally, we remembered one North American mammal known to undergo cycles in the northern parts of its range but not in the south: the snowshoe hare. This species is distributed across vast areas of Canada, Alaska, and—in the lower forty-eight—as far south as Colorado and Utah. In southern parts of the hare's range, numbers remain fairly even at all times, but farther north, it is strongly cyclic, peaking every ten to eleven years.

Even with the clear case of the snowshoe hare, we had to conclude that multiyear population cycles are not as common as was once thought. Nevertheless, they still have to be explained wherever they do occur. In northern Sweden, the three- to four-year cycles of several rodent species are strongly synchronized. Closely following the ups and downs of the rodents are their predators: as rodent numbers go, so go the numbers of weasels and owls that dine on them. And echoing, though with a slight time lag, the vicissitudes of both rodents and predators are the numbers of a few animals left pretty much alone most of the time, hunted only when voles and mice populations are declining. In North America, lynx, marten, fox, and other predators also go through cycles along with their prey, the snowshoe hare, as do some alternative prey, such as grouse and muskrat. In southern Sweden, little such variation, whether of predators or alternative prey, is evident.

I decided to investigate how predators in cyclic and noncyclic situations might differ. Again I turned to northern and southern Scandinavia. In the south, the numbers—both of species and individuals—of animals that feed on rodents are large. Foxes, hawks, badgers, and cats are most common, but there are others as well. I joined with Sam Erlinge and his students at the University of Lund to estimate the total predation on rodents over a fairly large area of southern Sweden. Our final calculations showed that 80 percent of the field voles and almost 100 percent of the wood mice (another species I decided to look at for this aspect of the study) were eaten every year. (The early age at which rodents reach sexual maturity and their very high reproductive output enables them to survive this level of mortality.) Our estimates also suggested that the number of predators in the area was pretty constant year to year.

How could the same number of predators be supported by a rodent population that can vary by as much as a factor of ten over the course of a year? The answer, it seemed to us, was that 80 percent of this predation on rodents was by generalists. In the winter and early spring of every year, when rodent numbers are low, the predators feed on a large number of vertebrate species, including rabbits, hares, pheasants, and amphibians. Then, as the summer breeding season draws to a close and rodent numbers are at their annual high, the predators switch to voles. Indeed, we found that there was very little delay between the increase in rodent numbers and a dietary shift of the predators. The relative lack of snow cover also helps these predators find food in the winter. Perhaps it is the predators' access to abundant alternative prey, and the speed with which they respond to increasing rodent numbers, that lead to stabilization of both their own populations and those of their prey.

Northern Scandinavia, in contrast, has fewer generalist predators, fewer individuals and species of alternative prey (no rabbits, for example), and long-lasting snow cover that protects voles for many months of the year. Recent studies by Henttonen and others in northern Finland have demonstrated that many of the common northern predators are almost totally dependent on a diet of small rodents. If a female weasel, for example, cannot get enough voles, she may not reproduce at all, may abandon her young, or even die. If vole numbers increase, so will weasel numbers, though never as quickly: the five or six pups born to a weasel cannot begin to compare with the twenty-five young a female field vole can produce in a single summer. In northern North America, the lynx shows a similar dependence on snowshoe hares.

Specialist predators, then, may be less

The bank vole, below, goes through extreme population cycles in the far north of Scandinavia, but not in the south. The catholic eating habits of such predators as the red fox, right, may partly explain why.
Asko Kaikusalo

able than generalists to keep the numbers of their prey down, allowing them to continue increasing, basically unchecked, until something halts the cycle. I wanted to know if food was the limiting factor. I examined the effects of voles grazing in both southern and northern Sweden. In the south, I found no evidence of overgrazing, whereas in the north, at least in years of peak vole numbers, I found evidence of heavy grazing not only on their staple foods but also on bark. Voles had girdled the bark of many of the young conifers in the forests I surveyed. Bark is not normally very nutritious, but just to be certain that the bark of northern trees didn't contain less fibrous matter and fewer indigestible substances (perhaps because of the shorter growing season), I took twigs from the same aspen clone and placed them in some northern and southern localities during an autumn of peak rodent numbers in the north. Hardly any bark was removed by rodents at the southern experiment stations, while the bark was almost completely stripped off in the north. Evidently, the northern rodents were simply hungrier and less particular about what they ate. Hungry hares in North America also eat bark as their populations peak and begin to crash.

Sooner or later, the rodents will die of starvation. And when they do, the predators that specialize on them will be in a desperate situation and will turn to whatever other animals they can catch—usually young hares or grouse in northern Scandinavia and grouse eggs or chicks and small rodents in North America. Within a year, the populations of both the predators and these alternative prey species will have declined as well.

So far the results of my tests and field observations have fitted my predictions that whether local predators are generalists or specialists has a strong impact on cycles in rodent populations, and that population peaks may be limited by food. However, I am not sure that I completely understand the phenomenon. Disease may be a factor, too, just as Elton suggested years ago. Studies of rodents that died during population crashes in northern Scandinavia revealed many diseased animals, and some of the same diseases have been found in humans during the same time periods. For example, when rodent numbers are very high, a kidney disease transmitted primarily by bank voles (through the urine and feces of animals entering houses) becomes common in people—but only down to about 61° north, that is, to the latitude at which rodent cycles start to disappear.

With a greater understanding of how and why some populations of small rodents undergo dramatic fluctuations every few years, we might prevent numbers from rising too high, for example, by setting out poisoned bait just as populations begin to increase. Many would cheer such efforts, for rodents are not only pests in forestry, horticulture, and agriculture, but they can also spread disease. In their northern habitats, where the fluctuations are most spectacular, these tactics would, however, be less likely to succeed.

As for me, I would miss the cycles. As an inherent property of northern ecosystems, I would like to see them continue. And beyond that, it is simply exciting to find the forests nearly empty one year, and then, one or two years later, to return and discover them flooded with rodents, their predators, and other animals drawn into the rodents' cycle of life. □

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Russia's American Adventure

For more than a century, traders from imperial Russia pursued their dreams in Alaska

by Lydia T. Black

On March 13, 1867, U. S. Secretary of State William H. Seward and Eduard Stoeckl, representing the Russian emperor Alexander II, signed the treaty by which the United States acquired Alaska, then part of the Russian empire. On October 18 of the same year, in Novoarkhangelsk (Sitka), the capital of Russian America, the imperial flag came down, and Gen. Lovell H. Rousseau formally accepted the vast territory for the United States. The ceremony did not go smoothly: the Russian flag became entwined in the ropes of the ninety-foot flagstaff, and it took considerable effort to bring it down. The episode is often cited in Alaska today—not always with amusement—when the imprint the Russians left on the land and its people is discussed.

Russian expansion to America had been initiated in the 1640s by private entrepreneurs ("the frontiersmen for the czar," one American scholar has called them), who reached the North Pacific from the Anadyr River basin, as well as by sailing south through the Bering Strait from the Arctic Ocean. The government followed on their heels. In the reign of Peter the Great (1682–1725), intercontinental expansion became a matter of policy. The first Russian port on the Pacific Okhotsk, was founded, local shipbuilding was established, the sea route to the Kamchatka Peninsula was explored, and charting of the North Pacific began. Peter the Great's design continued under his successors. In 1728 Commodore Vitus Bering sailed, with Capt. Alexei Chirikov, to the strait that bears his name. In 1732 another naval expedition made a landfall at Cape Prince of Wales, on the Alaskan side of the strait. And Bering and Chirikov again sailed across the North Pacific from Kamchatka to Alaska's Pacific shore, landing on Kayak Island and near modern

Ketchikan in 1741 and returning along the Aleutian island chain. Three quarters of a century later, on the basis of these landfalls, international conventions determined the boundaries of Russian territory on the North American continent.

By the eighteenth century, many of the settlers in Kamchatka and Okhotsk were engaged in the fur trade, an ancient occupation in northern Russia. When Bering's men returned and reported that marine fur-bearing animals were plentiful on the Aleutian Islands to the east, some traders naturally extended their operations. If the risks were great, so were the potential rewards. There were not only riches to be gained but also honors to be received from the crown for exploring new territories.

The Aleutian Islands extend in a great arc from mainland Alaska to the Commander Islands, near the Kamchatkan coast. Many are either the tips of giant submarine volcanoes or more ancient geologic formations dominated by active volcanoes. The islands are treeless and originally supported few land animals—lemmings and mice, red foxes (and their commercially prized variants, the cross, black, and silver foxes) eastward of Umnak Island, and caribou and brown bear

Crossroads of Continents: Cultures of Siberia and Alaska, *an exhibition featuring ivory carvings, clothing, masks, weapons, and other artifacts from Soviet and North American museums, is at the American Museum of Natural History from December 15 through March 25.*

A watercolor sketch of Novoarkhangelsk (Sitka), 1827, by Pavel Mikhailov

The Russian Museum, Leningrad

only on Unimak Island, off the Alaskan mainland. The human population was sparse, with the greatest concentration at the eastern end of the archipelago. The inhabitants spoke dialects of the Aleut language, at least two of which were so distinct that they were mutually unintelligible. (Other Native American groups the Russians encountered included the Inupiaq and Yupik Eskimo on the northern and western coasts of the Alaskan mainland; Alutiiq on the Kodiak archipelago; the Chugach [Koniag], Eyak, Tlingit, Haida, and Tsimshian on the Northwest Coast; and various Athabaskan-speaking groups, which generally occupied interior regions but also had coastal settlements along the Cook Inlet.)

All the Aleuts depended on the sea for subsistence, and their technology was superbly adapted for exploitation of marine resources: seals, sea lions, whales, seabirds, and fish. Nevertheless, there were significant cultural differences among local groups. These were organized into several large, named political units, which defended their territories and engaged in warfare. Boys were trained to be warriors from early childhood, and war parties had a structured chain of command.

At the same time, Aleuts engaged in long-distance trade with mainland Alaskan groups, primarily to obtain caribou products, copper, and iron. On rare occasions, they even traded with Japanese, other Asiatic, and possibly European seafarers. As a result, they were ambivalent about the arrival of the Russian intruders. Periods of peaceful barter and amicable personal relations were punctuated by outbreaks of violence, depending on circumstances and the character of Russian and local native leaders. Often, no quarter was given by either side. In the eastern islands, in 1763, Aleuts destroyed four Russian ships and nearly all their crew members, more than 200 men.

The Russian traders were known as *promyshlenniki* (today the term translates as "industrialists," but was then used to refer to those who left their communities on some sort of commercial enterprise). In the early period, most came from around the White Sea and other northern areas, the cradle of ancient polar navigation, the fur trade, and sea mammal hunting. A lesser but still sizable number came from Siberia and the Russian Far East and were often descended in part from native peoples, such as the Chukchi, Koryak, Yakut, Tungus, and Kamchadal. This is not always apparent in historical sources, since in Russia the ethnic ascription as well as civil estate was in the male line. A "Russian" from Kamchatka was thus very likely to have had a Kamchadal or Koryak mother. Moreover, in the early years of the Aleutian fur trade, many skippers enlisted Kamchatkan and Siberian natives as crew members. They were believed less likely to suffer scurvy and other diseases, and they understood the battle tactics of the Aleuts and were considered invaluable in conflicts.

For the *promyshlenniki,* neither the physical appearance of the local Alaskans nor their customs and manner of living were strange. Semisubterranean winter houses, summer fishing camps, skin boats, clothing made from the skins of sea mammals and birds, not to mention subsistence on salmon, halibut, cod, seal and sea lion meat, and drift whale carcasses, were all familiar, taken for granted. The fur traders often adopted the Aleut lifestyle, with modifications. They wore Aleut parkas and *kamleikas* (the waterproof shirt of sea mammal gut that is the prototype of modern rain gear), but added trousers, boots, and hats to their attire; they built semisubterranean dwellings and storage structures, but instead of using the roof entry and notched log ladders, they added doors, forerooms, and windows (made of translucent sea mammal gut, which the Aleuts used to cover their roof hatches).

The Aleuts in turn borrowed ideas and material items from the foreigners. Within ten years after first contact in the Near Islands, the Aleuts of Attu were extracting salt from seawater and using it

Only about 600 Russians lived in Alaska and the Aleutian Islands at the time Russia relinquished her foothold in America (map, left). The majority resided in the capital, Novoarkhangelsk, and on Kodiak Island. A Tlingit Indian's drawing, below, apparently depicts an initiate (second from right) of a secret society. It was prepared for Ilia G. Voznesenskii, who from 1839 to 1849 collected American ethnographic materials for the Russian Academy of Sciences. The nineteenth-century rattle, bottom right, was used by the Haida Indian shaman Tsilwax.

Academy of Sciences of the USSR, Leningrad

Smithsonian Institution; Collection of the National Museum of Natural History

to preserve fish. The steam bath, widespread in northern Europe and Asia, was quickly adopted and today survives as a native institution. Ironworking underwent a great change when the Russians introduced hot forging. Russian vessels usually carried a fully equipped forge and a blacksmith. In 1775, Ivan Solovev, leaving Sanak Island, left his forge to the Aleut leader. Russian carpentry tools and the Russian ax came into vogue. The axes are spoken of to this day, and in one family a full set of carpenter's tools is lovingly preserved as a treasured possession.

In the eastern islands, Russians distributed Siberian-style fox traps and encouraged Aleuts to trap the native foxes (which were not hunted in precontact times). In the Near Islands, not only traps but also arctic foxes from the Commander Islands were imported. Ground squirrels, now distributed throughout most of the archipelago, were introduced as fodder for foxes. (Today, models of the Aleut fox trap are sold to tourists, while the U. S. Fish and Wildlife Service, which is responsible for the Aleutian Islands as part of the Alaska Maritime National Wildlife Refuge, is exterminating arctic foxes because they are not indigenous to the ecosystem.) By the early 1800s, the Russians had introduced vegetable gardening, pigs, goats, and cattle.

Shamanistic practices, such as healing and forecasting, were also familiar to the Russians. Although they were devout adherents of the Orthodox Church, their folk beliefs had features in common with the Aleut world view. Sometimes they called on local shamans for aid when sick. Similarly, when Aleuts appealed for help because their shamans had given up, the

Dressed in his imperial navy uniform, Capt. Gavriil Sarychev visited the Chugach who had camped, with their overturned vessels, on Prince William Sound. He dined on sea otter, finding it rather palatable, like chicken. This engraving, from Sarychev's 1802 atlas, is based on a 1790 drawing by Luka Voronin. A double-headed eagle of brass, right, the imperial crest of Russia, entered the aboriginal trade network in the late eighteenth century and was interred in an Indian grave on the Columbia River, Oregon. It was rediscovered by archeologists in 1934.

Elmer E. Rasmusson Library, University of Alaska, Fairbanks

Russians would pray for them and perform rituals, such as lay baptism.

Russian laymen introduced Orthodoxy to the Aleuts many years before the arrival of clergy. The *promyshlenniki* often built chapels in their camps, and by the time the first missionaries arrived on Kodiak Island in 1794, the majority of people in the Aleutian chain and a number in the Kodiak archipelago and on the mainland considered themselves Orthodox Christians. The first church in Russian America, however, was built between 1795 and 1796 at Saint Pauls Harbor (the modern city of Kodiak).

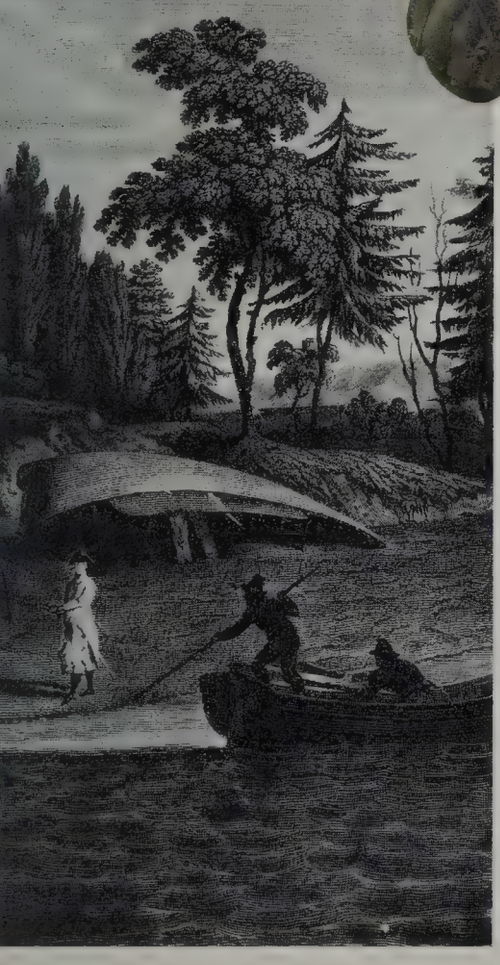
The use of the Russian language also found ready acceptance. With international trade and negotiation so important, many Alaskan native men spoke several languages. Learning to speak the language of the newcomers was considered nothing special. Some Russians learned to speak Aleut, but most needed interpreters. Often they took young boys to their camps, where they were taught Russian, or sent them to school in their home ports. Aleut leaders sometimes volunteered their young kinsmen so that they would learn the language and gather as much intelligence about the foreigners as possible. More often, the boys were hostages, held at the Russian camps to insure peaceful relations with the Aleuts.

Holding hostages to guarantee safety and peace was an ancient practice both in Siberia and among native Alaskans. Russians always asked for hostages or took them by threat of force. Occasionally, a Russian was left as a hostage in a native community. In 1796, six Russians were left as hostages in the Tlingit settlement at Yakutat, on the Alaskan coast, to insure the safe return of the chief's son, who was sailing to visit the Russian community on Kodiak Island.

Because Aleut women were not valued very highly, the Russians preferred male hostages, neither so old as to become a danger within the Russian camp nor so young as to require special care. Russian men, perhaps fathers or elder brothers lonesome for home and family, often formed genuine attachments to their hostages. They introduced them to Orthodoxy, baptized them by lay baptism, and gave them Russian names. Such a godson was given a Russian Christian name and a name based on the godfather's Christian name, as well as his godfather's family name. This practice explains, more often than actual paternity, the prevalence of Russian surnames in Aleut communities of the Aleutian and Kodiak archipelagoes, as well as among other Alaskan groups that came under the Russian scepter. Sometimes slaves held by the Aleuts or young Aleuts without kin were adopted and taken to Russia.

British and "Bostonian" (American) sea otter and fur seal traders, who began operating on the Northwest Coast beginning in 1785, traded from their vessels only during the summer sailing season and seldom established shore camps. The Russian practice, in contrast, was to establish a winter camp, beaching the vessel in a convenient stream or lagoon. Such camps served for at least a year, but more often for several years and sometimes for as many as ten. Leaving a skeleton crew at the vessel, the Russians would disperse in small groups to hunt the furbearers. They also bartered with the Aleuts for additional furs.

Smithsonian Institution; Collection of the National Museum of American History



As a rule, these hunting parties set up their own camps, often near established Aleut settlements. Occasionally, a solitary hunter or a small group of men took up residence within an Aleut community. Since the fur-trading vessels, according to available records, did not carry women, Russian-Aleut unions inevitably developed. While forcible abductions of women occurred, some women joined Russian camps willingly or at the behest of their male relatives.

By and large the *promyshlenniki* were God-fearing men, and a number sought to legalize their unions with native women and provide for their children to inherit their estates. Sometimes the unions were solemnized by following Aleut matrimonial customs. Often, in addition, a written contract would be drawn up and sworn to on the cross or the bible by the man concerned and the witnesses—other Russian *promyshlenniki*, Alaskan native leaders, and relatives of the bride. When the first clergymen came, one of their first tasks was to bless these marriages, making them fully legal and unbreakable.

Children of Russian–native unions often grew up bicultural, and as early as the 1760s, some *promyshlenniki* were teaching their young hostages, godchildren, and their own and their friends' childen to read and write. By the 1770s the Russian government issued charters that gave Aleuts rights as subjects of the empire and provided protection against any arbitrary violence on the part of the Russian skippers. Aleuts treasured such charters and other written documents and learned to write Russian themselves.

In the nineteenth century, Orthodox clergymen, of whom the most prominent in Alaska was Ioann Veniaminov (now Saint Innocent of the Aleutians), introduced writing systems for a number of Alaskan languages. The first publications in the new scripts were the Gospels and church service books, but the Aleuts also began to use the scripts for secular literature and everyday communication.

Despite the cultural exchanges, however, the Russian presence in the islands caused massive social dislocation. Participation in the fur trade changed the economic system of the Aleuts in short order. Aleuts often traveled long distances or resettled in order to gain access to Russian trading vessels or to particular trading partners. This facilitated the spread of diseases, both indigenous and newly introduced. The greatest scourges during the early period were venereal and intestinal infections and probably tuberculosis.

Smallpox may have touched the Tlingit sometime prior to 1786 (when a British skipper reported seeing some pockmarked individuals on the coast), but the disease did not really strike Alaska until 1835. Russian administrators attempted to check the epidemic by vaccination. Although many people were vaccinated, and in some islands the disease was prevented, the Russians were unsuccessful on the mainland and on Kodiak Island. Not only were they unable to reach many segments of the population, but the Alaskan natives often resisted vaccination because the procedure contradicted their theories of what causes disease. This was the case for the Tlingit, among whom casualties were extemely high, the Yupik, and the Kodiak islanders. Ironically, among the Yupik the belief persists that the Russians purposefully injected the natives with the disease, a belief based on the vaccination effort. The lesson was learned, however: a major American smallpox epidemic in the 1860s did not spread to Alaska, largely owing to

The Limestone Press

Aleksandr Baranov, visionary or villain?

Painted by Mikhail Tikhanov in 1818, a Tlingit warrior wears hide armor and carries a flintlock and a native dagger.
I. E. Repin Institute of Painting, Sculpture, and Architecture, Leningrad

the efforts of the clergy, who promoted a new vaccination program.

Systematic economic exploitation of the Aleuts, specifically in the eastern Aleutian Islands and in the Kodiak archipelago, developed toward the end of the eighteenth century. The fur trade changed from local entrepreneurs to large-scale capital enterprises, and as the competition increased, the skippers were pressed by the owners for profit. Always short of labor, they resorted to impressment of Aleuts, carrying them off to mainland Alaska, to the Pribilof Islands, and even resettling them in new outposts. This left the villages with the women, the old, and the young, who were often unable to insure their own subsistence.

In 1790, Aleut leaders on Unalaska Island bitterly protested these practices to an imperial navy expedition that had been sent by Catherine the Great. The Aleuts were careful to point out that not all skippers were to blame and named those with whom they liked to trade and for whom they liked to work. Those accused of the most grievous abuses were all in the employ of the merchant Grigorii Shelikhov.

Shelikhov had entered the Siberian fur trade in the 1770s. From the beginning, his interests extended from Kamchatka and the Kuril Islands to Alaska. Soon he held a controlling interest in many ventures, gradually squeezing out his partners and his competitors. By 1780, he had grandiose plans to build an empire on the American continent and was continually importuning the government for support of his "services to the state." Although the empress was more than skeptical, Shelikhov managed to enlist considerable official backing. In 1783 he sailed from Okhotsk for Russian America with permission to carry more than the usual armament on his three vessels.

For Shelikhov, acquisition of furs was a means of amassing capital to build his empire. He wanted to settle Alaska, build cities, industry, agriculture, cathedrals, schools—from the Northwest Coast to Bering Strait and beyond. To establish a permanent stronghold, he chose the most populous region known, Kodiak Island, bypassed by most skippers because of the highly organized strength of the indigenous inhabitants. Contrary to government policy, he directed an armed conquest, on the premise that what the government did not know was not going to hurt it. This was accomplished in a series of swift, sudden, and even by the standards of the time, brutal strikes.

Shelikhov left Kodiak in 1786, but by 1791 he had found a man eager to carry out his wishes—Aleksandr Baranov. An able leader and a skillful diplomat, Baranov used Kodiak islanders as his main labor force and impressed them into his "army." Although Shelikhov died in 1795, his company continued to operate and was granted a monopolistic, twenty-year charter by the emperor Paul I in 1799. Baranov then became the general manager of the Russian American Company, ruling as a de facto governor.

During Baranov's reign, with Europe in the grip of the Napoleonic wars, Russian ships could not regularly be spared to supply the needs of the colony. Taking matters into his own hands, Baranov began shipbuilding in Alaska. In 1796, the first three-masted ship was launched at Voskresenskii (now Seward). Smaller vessels were built at other locations, while several ships were bought from the Americans. A colonial merchant fleet came into existence. American skippers were tempted by Baranov to carry cargo from the eastern seaboard of the United States and from Canton, China, to the Russian settlements in Alaska in exchange for furs. A linkage with John Jacob Astor's enterprises was in the works.

Aided by his army of impressed Aleuts and various volunteer contingents, Baranov checked the British and American competition along the Northwest Coast and established Novoarkhangelsk as his capital in the Tlingit territory. He weathered the armed conflict with the Tlingit (who were aided by British and American ordnance and several American sailors), sent out exploring parties to the Columbia River, established Fort Ross in California in the face of Spanish opposition, and attempted to gain a foothold in Hawaii. His kayak fleets ranged to Baja California for sea otter, fur seal, and salt.

An early nineteenth century ivory carving by an Aleut represents a Russian in Kamchatka-style clothing.
Etholen Collection of the National Museum of Finland

Baranov's achievements notwithstanding, adverse reports by the clergy and navy personnel resulted in his removal in 1818. Reform followed: native impressment ended, and in accordance with the Russian system of social ranking, in which each rank had different duties and rights, Aleuts were assigned a status equivalent to that of free peasants. In lieu of taxes and military service, a certain number of Aleuts from each village had to serve with the company, primarily as sea mammal hunters, and were paid set wages. Local Aleut leaders managed native affairs, including the selection of those who were to serve in the company.

In 1821, following negotiations, the Russian American Company received a second charter, which imposed new responsibilities. Fur seal and sea otter conservation measures were instituted and eventually enforced. In the fur seal rookeries in the Pribilof and Commander islands, only nonbreeding adult males were taken. Periodically, the harvest was discontinued for a number of years. Any use of firearms or establishment of settlements near sea otter hauling grounds was forbidden, and only a limited number of skins were taken per year. In areas where the Aleuts hunted sea otters and sold them

Drawn by Louis Choris (ca. 1817), an Aleut man, below left, wears traditional hunting garb, while an Aleut woman wears Europeanized clothing, braids, and a Russian Orthodox cross. Featuring a paddling figure carved in ivory, an Aleut visor, right, was imbued with spiritual power and symbolism.

Smithsonian Institution; Collection of the Anchorage Museum of History and Art

Museum of Anthropology and Ethnography, Leningrad

to the company on an independent basis, there was some discontent, as furs in excess of the established quota for the district were not bought. Immature and female sea otter skins were also refused.

The company was obliged to provide services to the population, such as churches, medical outposts manned by paramedical specialists, and schools. Open to all, the bilingual and bicultural schools taught basic literacy skills, religious studies, mathematics, geography, history, music, and art. Educational opportunities were especially favorable for the members of a newly created Alaskan rank, or estate, called creoles. Creoles were persons who could claim descent in the male line from a Russian. Sometimes an Alaskan native was considered a creole if he occupied a position of responsibility within the company.

Likened to the burghers in Russia, the creoles could (and often did) become company officials or achieve military or naval officer rank. By the end of the Russian period, this class provided the backbone for the Russian Alaskan enterprise. They explored the Alaskan interior and North Slope, established trading posts and trading networks that crisscrossed the entire territory, and commanded company ships. They were managers, shipbuilders, artisans, medics, and physicians. Some served in the navy, others became artists or priests. High-ranking visitors from Saint Petersburg often ridiculed this class as social upstarts, while Russians of lower ranks resented the creoles' social mobility and the educational opportunities and other privileges granted them.

With the advent of U. S. sovereignty, the creoles suffered great degradation because Americans considered them contemptible "half-breeds." Today, the majority of their descendants are absorbed in the Alaskan native communities; others moved out of Alaska and blended with the "white" population of the other states.

Russians were never numerous in Alaska. At times there were fewer than 200. By 1830, the number was about 300 and slowly growing. From the 1840s to the end of Russian America in 1867, they numbered just under 600, of whom nearly 500 resided in Novoarkhangelsk or on Kodiak Island. There were no troops stationed in Alaska at all before the Crimean War (1853–1856). At that time the Russians, fearing the British would attack or incite Tlingit unrest, brought one hundred soldiers from Siberia to man Novoarkhangelsk's defenses. They were mostly employed in various tasks in the harbor

Tlingit gambling sticks were shuffled and divided into two bundles; players then guessed which bundle contained a specific marked rod.
Smithsonian Institution; Collection of the National Museum of Natural History

and around the town and were not used to subjugate the natives.

The level of violence in Russian America after 1818 was remarkably low. Governmental policy prohibited retaliation against acts committed by Alaskan natives, maintaining a legal fiction that any such acts were the result of provocation by the company's employees. Gifts were exchanged to reestablish relations after a violent incident. Noninterference in native affairs was a matter of policy. The Russians were often called in as a neutral party to settle disputes between native groups and between the Tlingit and the Hudson's Bay Company trading post near modern-day Wrangell.

Crime was exceedingly rare among the Russian colonists as well. The general manager acted administratively when employees transgressed company regulations, but had no jurisdiction in either civil or criminal cases. When a crime was committed, the accused and the witnesses were shipped to Russia for judicial proceedings. There were no courts and no jails in Alaska during the Russian period.

In the beginning of the Russian period, the fur trade was the driving force of the colony, but by the middle of the nineteenth century the situation was changing. As fur markets in Europe diminished and the Chinese market collapsed, the company attempted economic diversification. Ice was shipped to San Francisco, coal to Vancouver and Victoria and to American ports farther south, and fish to places as far away as Hawaii. None of these ventures fared too well. Better coal was found in British Columbia and was less expensive to ship to the American cities. In the absence of canning technology, Alaskan salted fish found but a small market.

The Russians were aware of the region's iron, copper, and gold (although they never identified major gold deposits), but they never exploited these minerals. Historians do not agree if behind this inattention was ignorance of the true potential of the area or the fear that the territory would be overrun by fortune hunters from the United States and Canada. I incline to the latter view: in Russian documents, the California and Stikine River gold-rush stampedes are often mentioned with alarm as horrible examples of what might befall a country once greed is awakened on a mass scale.

Nevertheless, the Russian American Company's long-term economic prospects remained good. The Russian period ended because of a government move. In the wake of the Crimean War, the navy's capacity to protect Alaska from British expansion seemed doubtful. Besides, the government wanted to consolidate its position in the Amur region on the Chinese border. The decision was taken to retreat from Alaska. The United States, then friendly toward Russia, was invited to purchase the territory for a modest price.

The Russians in Alaska did not foresee nor desire this outcome. When the ceremony of transfer commenced on October

Fitted with a homemade stand, a Russian flintlock was used by a Chukchi hunter in the Russian Far East.
Smithsonian Institution; Collection of the American Museum of Natural History

18, 1867, few Russians attended, aside from those present in an official capacity. An American witness commented:

> Alaska is the fatherland—native soil. . . . They would be less than human were they to regard this cession of the country with any other than feelings of sadness. . . . Let me not be misunderstood. The Russian citizens of Sitka are loyal to their sovereign, and submit to his mandate peaceably and without complaint. There has been no repining, no exhibition of moroseness or ill-will toward our people. Yet it was impossible for the more patriotic of the resident population not to have a feeling of sorrow while seeing the flag under which they were born lowered from its time-honored position, never again to float over their island home.

Within three years after the transfer, the majority of Russians, some creoles, and even a few Alaskan natives chose to repatriate to Russia. A few Russians remained in Alaska, some intermarrying with the immigrants who flooded the territory from the United States and Europe. The newcomers came as businessmen, sea otter and fur seal hunters (under new laissez-faire policies), whalers, and finally, in unprecedented numbers, as gold seekers. Except in the Alaskan native communities, few families in Alaska today trace their descent to the Russian settlers.

Nevertheless, the Russian Orthodox Church retains a central place in Alaskan culture, and other aspects of local life, such as the cuisine and folk dancing, still bear a Russian stamp. Today, partly because Alaskan native groups have called for better teaching of their own history, a new generation is examining this heritage. Conferences, exhibits, documentaries, and efforts to preserve churches and other historic structures are reviving interest in Russian America, as are the inevitable tourism promotions. And when the state celebrates Alaska Day each October 18, citizens of Sitka gather to commemorate, and reenact, the transfer from Russian to U. S. sovereignty. At the end of the ceremony, the Russian American Company flag, which on holidays flies alongside the state flag and the Stars and Stripes, is raised on the hill where the general manager's house once stood. □

The multi-ethnic Klinkovstrem family, ca. 1871: Martin (seated at right), born in Latvia, was a German then serving as the Russian consul general in San Francisco. His wife, Evgenia F. Kolmakov (seated at left), was a "creole": her father was Fedor Kolmakov, a Russian who worked for the Russian American Company, while her mother was a native from Katmai, on the Alaska Peninsula. Their daughter Evgenia, left, stands next to her husband, Henry S. Craven, of the United States Navy; daughter Olga, right, is joined by her husband, Nicholas Sedletzky, who was in the Russian navy. Daughter Sophia, center, is shown with her daughter by her first marriage, Evgenia Koshkin. Sophia later married Lt. Boris de Livron of the Russian navy.

The Collection of Richard A. Pierce

Let's dig a little deeper into the notion that much of our garbage is made up of plastics.

America's growing waste problem is monumental. We generate 160 million tons of garbage a year.

Our nation's landfills are being filled up. In five years 2,000 of our remaining 6,000 landfills will be closed.

A lot of well-intentioned solutions are being offered. One is that foam plastics, plastic bottles and plastic packaging should be banned.

The fact is that plastics make up less than 8%, by weight, of our nation's waste. Paper and paperboard make up about 36%, glass and metal about 9% each, all by weight. Plastics are naturally lighter, but still, when compressed, account for only about 20% by volume.

If plastics were banned, the need for packaging wouldn't go away. The idea is to substitute other materials which are assumed to be biodegradable, so a landfill would take longer to become full. Studies show, however, that paper and other materials decompose so slowly in today's landfills that the lives of the landfills are not extended.

Recycling must play a part.

In addition to environmentally secure landfills, and more state-of-the-art waste-to-energy incinerators, we believe that a significant answer to America's waste problem lies in recycling. Everything recyclable should be recycled. Yard waste. Paper. Metal cans. Glass bottles. And plastics.

Although plastics recycling is in its infancy, plastics are potentially more recyclable than alternative packaging materials.

In South Carolina, one company recycles 100 million pounds of 2-liter plastic soft drink bottles a year into everything from fiberfill for ski parkas to scouring pads to automobile distributor caps.

In Chicago, another company processes 2 million plastic milk jugs a year into thousands of boards of "plastic lumber" for boat docks, decking, park benches and fences.

In Tennessee, another company processes plastic containers into bathtubs, shower stalls and sinks.

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Illustrations by Donna Braginetz

"Mountain runner" dinosaurs emerge from their eggs on long, sturdy legs and are able to forage for plants, catch and eat insects, and elude predators.

Dinosaur Eggs: The Inside Story

Tiny bones have helped paleontologists answer some big questions

by John R. Horner and David B. Weishampel

Late one afternoon in July 1979, Fran Tannenbaum, a Princeton paleontology student doing summer fieldwork, found a complete, 75-million-year-old fossil egg atop a grassy hill west of Choteau, Montana. As soon as she alerted them, her fellow crew members joined her at the hill. Searching through the dirt on hands and knees, they uncovered eleven partial eggs by nightfall. In the next few weeks, by screening the top layer of sediment on the hill, the crew uncovered portions of nearly fifty eggs and an abundance of small dinosaur and lizard bones. The surface sediment of the hill continued to yield eggs and bones for the next two summers.

In 1982, a field crew led by John Horner and Bob Makela began jackhammering deep into the hard core of the hill, by then dubbed Egg Mountain, and during three field seasons, they excavated one hundred tons of rock. The mother lode of fossils in Egg Mountain included twelve whole clutches, or nests of eggs, and more bones. At the end of the 1983 field season, the crew found three clutches in another nesting ground, which they named Egg Island. One of these clutches consisted of nineteen eggs, each containing the rarest and most fragile of fossils—complete, nearly full-term dinosaur embryos.

Analysis revealed that the nests and many of the skeletal remains and eggs belonged to a previously unknown species of hypsilophodontid dinosaur, and we used X-rays and CAT scanners to confirm that the eggs did indeed contain embryos and that they were of the same species. We christened this new, long-legged, ten-foot species *Orodromeus makelai,* or "Makela's mountain runner." (The other fossils from Egg Island and Egg Mountain included the skeletons of shrewlike mammals, a varanid lizard, a small carnivorous dinosaur known as *Troodon,* and *Troodon* eggs.)

The extensive, fossil-rich badlands of west-central Montana, part of what is known geologically as the Two Medicine Formation, have so far proved to be the most fertile territory in the world for uncovering evidence of nesting dinosaurs and details of their growth and life history. The rocky layers of the Two Medicine Formation are a record of life in this area 84 to 72 million years ago in the late Cretaceous. (The dinosaurs died out some 65 million years ago.) Within the formation, a smaller landform, a kind of rock "wrinkle" called the Willow Creek Anticline, was the setting not only for the *Orodromeus* find but also for the Horner-Makela team's 1978 discovery of the nesting grounds of a duck-billed dinosaur, or hadrosaur. The eggs, nests, and skeletons of adults and hatchlings found on land owned by the Peebles family provided the first clear evidence that some dinosaurs actively cared for their young in the nest, and the hadrosaur was accordingly named *Maiasaura peeblesorum,* or "Peebles' good mother lizard." Despite a relative abundance of maiasaur eggs, no maiasaur embryos were unearthed until 1984, when tiny, disjointed skeletons were found amid eggshell fragments in a nest.

Because abundant remains of adults, juveniles, hatchlings, and now embryos have come to light, *Orodromeus* and *Maiasaura* are the two best-known dinosaurs in terms of stages of development. They present completely new ways of deciphering the biology, life styles, and evolutionary history of dinosaurs. They are not, however, the first dinosaurs known from a variety of age classes. The Central Asiatic Expedition undertaken by the American Museum of Natural History in the 1920s found nests and eggs of a small horned dinosaur, *Protoceratops,* in the Gobi Desert. Further work on the Gobi material by paleontological institutes in Warsaw, Moscow, and Ulan Bator in the Mongolian People's Republic has provided a fund of information on *Protoceratops* growth stages. More recently, embryonic remains of an early herbivorous dinosaur, *Massospondylus,* were found in association with eggshell fragments in South Africa, and eggs containing embryos of the crested hadrosaur *Hypacrosaurus* have surfaced at the Two Medicine Formation both in Alberta, Canada, and in Montana.

What kinds of information can a paleontologist extrapolate from fossil nests, eggs, and embryos? First, the pattern of eggs within a nest (sitting upright or ar-

Fossil Babies or Little Adults?

ranged in concentric circles or a spiral) and where the clutch was placed (in a specially constructed, insulated nest, or simply in a depression) are clues to the egg-laying habits of the female. Second, close spacing of nests suggests that the animals nested communally, as many seabirds do today. Third, the thickness and surface features of the eggshell—for example, bumps, ripples, or pits—reveal something of the embryo within, at least in terms of gas exchange between it and the outside environment. Fourth, in cases in which an embryo is found in close association with the remains of an adult, information on possible live birth, or viviparity (see sidebar), and on possible parental nurturing can be derived. Finally, the anatomy of the embryo sheds light on its course of development and on whether the young were helpless or fairly independent at the time of hatching.

During the past ten years, the wealth of physical evidence of nesting dinosaurs from Montana's Willow Creek Anticline has fueled speculation and given impetus to broad new theories on how at least two species of dinosaurs hatched, grew, attracted mates, reproduced, cared for their young, socialized, and migrated, and finally, on how some individuals died. The evolving picture of how these complex, sophisticated creatures lived toward the end of the age of dinosaurs has helped to dispel earlier views of dinosaurs as overgrown, pea-brained sluggards. The *Orodromeus* and *Maiasaura* fossils, all found within a two-square-mile area, offered us the rare opportunity for comparisons between species. The differences we found were enlightening.

Both *Maiasaura* and *Orodromeus* lived and nested on what was then an upper coastal plain flanking the emergent Rocky Mountains, about 200 miles from the Western Interior Cretaceous Seaway. Until about 65 million years ago, when it dried up, this sea stretched from the Arctic to the Gulf of Mexico. *Maiasaura,* which lived some 80 million years ago, was a sturdy, twenty-five- to thirty-foot, 3,300-pound herbivore that walked on its hind legs but browsed and stood on all fours. *Maiasaura* had a stout crest, a hadrosaur

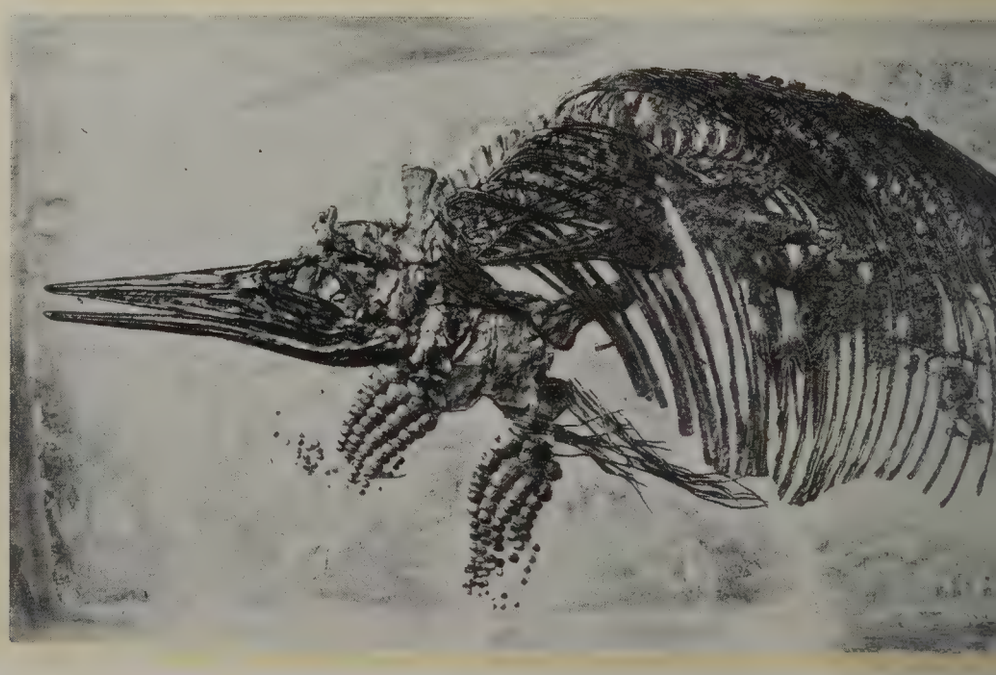
Two recent studies on embryonic remains of fossil reptiles other than dinosaurs can help to demonstrate how paleontologists follow clues to solve some of the mysteries of long-extinct creatures.

The fishlike ichthyosaurs, ocean-going contemporaries of the dinosaurs, have long been known from the fossil record. In 1846, tiny ichthyosaur remains were found buried within those of adults. While some scientists believed that the fossils were evidence of ichthyosaur cannibalism, others argued persuasively that the adult remains represented pregnant females and that the miniature fossils were near-term embryos. Since then, well-preserved fossils of embryos still in utero and others literally caught in time at the moment of birth have proved that ichthyosaurs gave birth to living young and have provided singular and intimate information about ichthyosaur life history.

In 1979, Rosemarie Johnson, now at the Royal Ontario Museum in Toronto, used ichthyosaurs as a starting point in tackling a perennial problem in paleontology—how to distinguish juveniles of one species from small adults of another. (Several museum collections contain baby dinosaurs misidentified as adults of other, smaller species.) Johnson used modern reptiles as models for the development of limb bones and joints. The ends of limb bones in young crocodilians and turtles consist of a large cap of cartilage overlying not yet completely developed bones. Underneath the cartilage caps, the bone surfaces are heavily pitted. As crocodilians and turtles grow, the cartilage thins to form a strong covering over the ends of long bones, so that the surfaces of joints mesh smoothly. Fossil ichthyosaurs show a similar development. The limb bones of tiny ichthyosaurs within the abdomens of larger ones are always poorly formed and very pitted. The articular surfaces of the larger ichthyosaurs, in contrast, are well formed, and joints are smooth and congruent.

Johnson's crocodilian-turtle model also allowed her to measure and compare relative sexual maturity and bone maturity. She found that sexual maturity was independent of absolute size in the species she studied; ichthyosaurs were able to reproduce before their bones had stopped growing. Johnson also used her bone studies to determine the approximate ages of ichthyosaurs from a variety of species, many of which turned out to be immature members of different species. The ability to evaluate relative age independent of size would have been impossible without the existence of embryos and their association, not with cannibals, but with their mothers.

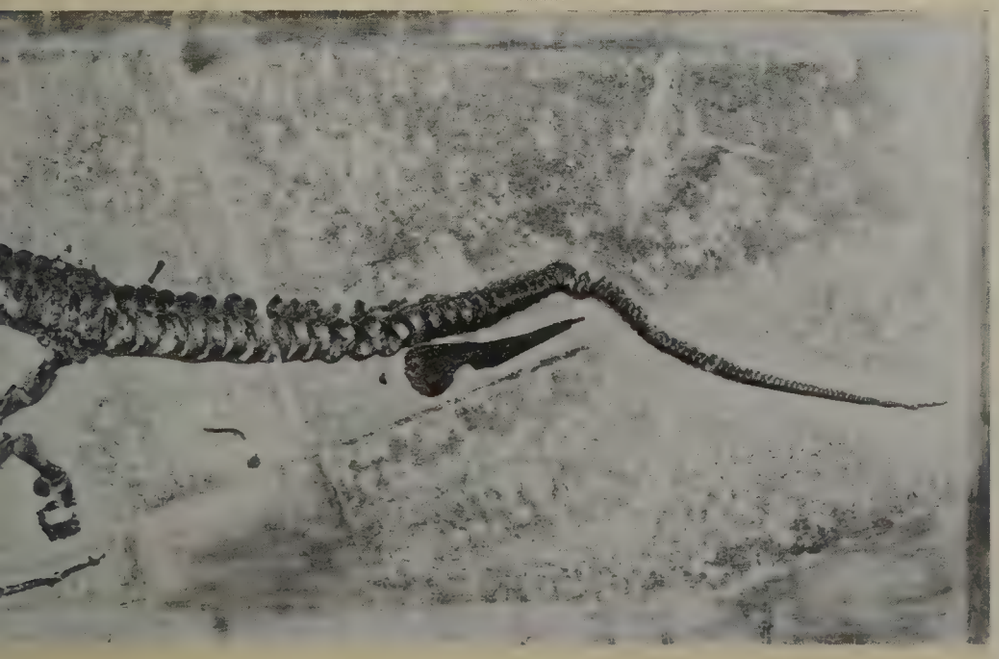
Nothosaurs, too, were marine reptiles, but they were able to haul-out on land, and they solved the problems of aquatic locomotion, feeding, and reproduction somewhat differently from the ichthyosaurs. In contrast to the long fossil history of ichthyosaurs, no early stages of nothosaur life had been identified until recently. In 1988, Martin Sander, of the Paleontology Institute and Museum of Zurich, Switzerland, announced the discovery of a 230-million-year-old fossil nothosaur embryo. Just one of a trove of fossils unearthed in the alpine region known as Monte San Giorgio near the Swiss-Italian border, the embryo belongs to a new species of *Neusticosaurus*, a nothosaur of warm coastal waters. Eight hundred fossil individuals of this new species found over time at Monte San Giorgio



provide the basis of a growth series that shows distinct sexual dimorphism among adults, that is, one sex was much larger than the other. Sander believes that the two-inch-long, large-eyed embryo was two thirds of full-term size at its death. Like ichthyosaur embryos and newborns, the tiny *Neustiosaurus* had an incompletely developed skull and underdeveloped limb bones. The body is curled up, the head near the tail, a pose typical of vertebrate embryos. No adult fossils were in such proximity to the embryo that they are candidates for mother, but the absence of any bits of eggshell suggests that these animals may have borne live young and that this embryo had been aborted.

A two-inch, 230-million-year-old fossil embryo of a small species of nothosaur
Martin Sander

A fossil ichthyosaur, a marine reptile, containing unborn young
AMNH



trait, just above its eyes, and the jaw in its long snout harbored a set of 200 functioning teeth with another 600 as eventual replacements for teeth shed over time. *Orodromeus* was relatively small at ten feet long and had disproportionately long, muscular hind limbs. Limb biomechanics suggests that it was able to reach a speed of about twenty miles per hour. At this rate, the mountain runner could certainly have eluded its enemies, such as the hefty, meat-eating *Albertosaurus* and the small carnivore *Troodon,* even more fearsome because of its agility and trenchant weaponry. The narrow, triangular teeth of *Orodromeus* suggest that it fed on a combination of fleshy fruits, succulent foliage, and insects.

Orodromeus eggs from Egg Mountain and Egg Island are smooth in texture and about seven inches long and three inches wide. Nearly all were found as lower halves or thirds, indicating that the hatchlings had emerged prior to the eggs' entombment. The spiral clutches (no nests were constructed) contain an average of twelve eggs, laid upright or slightly inclined toward the center, with the lower halves embedded in the soil. This arrangement is similar to that of eggs of *Protoceratops* found in the Gobi and of modern megapode birds, such as the jungle fowl of Micronesia. Presumably it optimizes gas exchange—oxygen infiltrates the shell and carbon dioxide escapes. It also allows the struggling infants an easy exit; they only have to pop the lid off. How the mother *Orodromeus* went about arranging her eggs in a spiral calls for some paleobiological interpretation. She could have simply rotated her body as she deposited the eggs, but the precision of the spiral and inward slant of the eggs suggest otherwise. We think a more logical explanation is that the mother deposited the eggs first and then manipulated them with her front feet and beak. Unusually large clutches of twenty-four eggs may contain the deposits of two females, which were combined and rearranged.

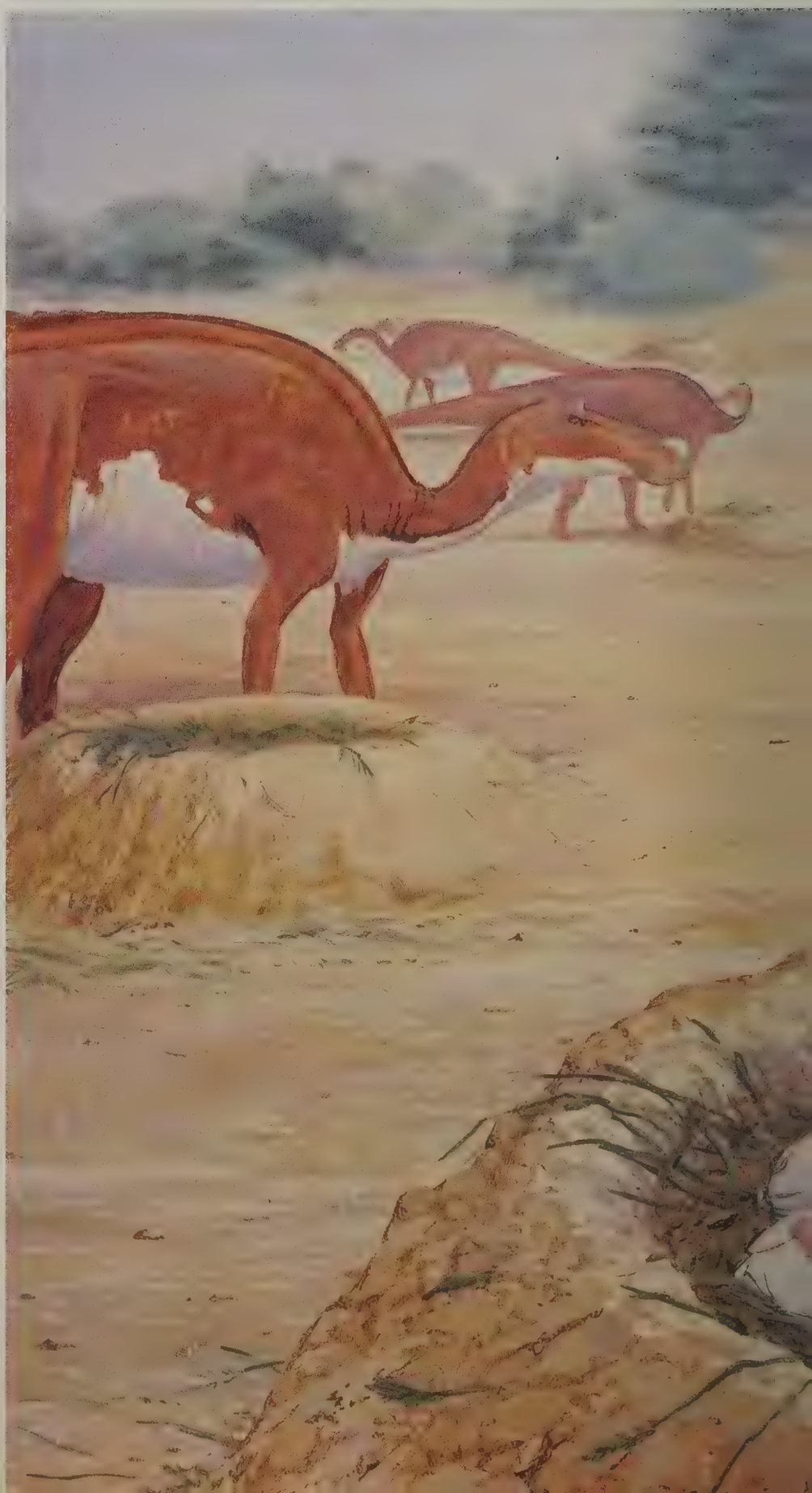
As in a teeming penguin colony, many mothers or perhaps pairs gathered during the breeding season to lay their eggs collectively. The nests are about as far apart

as the length of an adult hypsilophodontid, so the space was used with maximum efficiency. Because we have found successive fossil layers with similar nest patterns, we believe that these dinosaurs may have returned to the same area year after year. Empty *Orodromeus* eggs are usually found as neat, unbroken lower halves or thirds, rather than as trampled piles of shell fragments, indicating that the infants must have vacated the nest right after they hatched.

Maiasaura eggs, in contrast, are seldom preserved whole or even mostly intact. Instead, they are found as roughly circular clusters of fragments of from twenty to twenty-five eggs. The circles strongly suggest that the mothers laid and arranged their eggs much as *Orodromeus* did. The crenelated, lopsided, ellipsoid eggs, however, were larger, about eight inches long, and were laid in nests about six feet wide and three feet deep. Each bowl-shaped nest that we found appeared to have been made of mud piled up on the ground. The closely packed nests were separated by about twenty-five feet, approximately the length of an adult maiasaur. From the different sizes of fossil hatchlings, we know that maiasaur young, about fourteen inches long upon emerging from the egg, were nestbound until they were five feet long. The presence of such hefty infants crawling about the nest accounts for the lack of intact eggs.

After the discovery of maiasaur embryos in 1984, we were in a position not only to conduct a direct comparison between embryonic and adult skeletons but also to compare embryo growth stages for our two dinosaurs. The results led us to address broader questions about how dinosaurs reared their young.

The near-term maiasaur embryos have a full complement of skull and skeleton bones, and the teeth have erupted. But most of the skeletons are not yet fully developed and are often spongy in texture. For example, the articular surfaces, where joints will form at the ends of the thighs, are spongy and incomplete because of a preponderance of cartilage. Fully functional, bonier joints appear only in the limbs of juveniles that have grown to a



In a large colony of nesting dinosaurs, baby maiasaurs hatch under the tender care of a parent. Nurtured by the adult, the helpless young will grow rapidly, more than doubling their size before they venture out of the mud nest.

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length of three feet. The bones of *Orodromeus* embryos reveal a far different development. The cartilage is thin and calcified, and joints are well formed.

The walls of limb bones reveal something important about the growth rates of vertebrates. On the outer surface, material known as periosteal bone is laid down and then internalized as more bone forms on the outside. Vessels that carry blood through this area become trapped. Under a microscope, a cross section of periosteal bone reveals the number of vessels and the inner structure of the bone. Slow-growing vertebrates, such as amphibians and reptiles, have few trapped vessels and have lines, like the growth rings of trees, that indicate where growth started and stopped and started and stopped again. In the bone of warmblooded, fast-growing birds and mammals, vessels are abundant, and only the bones of old individuals have lines that mark the cessation of growth. The bones of *Maiasaura, Orodromeus,* and all other dinosaurs for which a number of growth stages are known are like those of birds and mammals.

Both species, as evidenced by their bone structure, grew as rapidly as warmblooded animals. And both nested in congregations probably every bit as crowded, noisy, smelly, and filled with life as any huge, guano-strewn seabird colony today. Such bounty is sure to have attracted predators, and dinosaur mothers or fathers or both most likely guarded their eggs. Thus far, the two species of dinosaurs have much in common.

Maiasaura mothers, however, seem to have constructed a roomy mud nest and to have placed an insulating layer of vegetation over the eggs. (The 1½-ton adults could not have sat on the clutch.) Some modern birds do the same. Also, like birds that are altricial, or helpless upon hatching, the rather limp baby maiasaurs stayed in the nest and were fed regurgitated foliage and berries by a parent until their bones were strong enough to allow walking or running. They grew quickly, more than doubling their considerable size as nestlings. When they were about five feet long, they were finally able to leave the nest and forage with adults.

With their fully developed limbs and joints, and like precocial birds such as megapodes, *Orodromeus* hatchlings were capable of both walking and running as soon as they emerged from their eggs. Camp followers such as lizards and the lithe, carnivorous dinosaur *Troodon,* which left many teeth in the colonies, must have eagerly snatched up and devoured untended eggs and slower hatchlings. Perhaps juvenile *Orodromeus*

dashed about in groups to evade predators. Among other characters at the *Orodromeus* colonies were many fossil insects that resemble carrion beetles and that may have cleaned up the leftovers from hatched or broken eggs.

Other aspects of dinosaur biology, particularly that of the well-known hadrosaurs, fit into the context of reproduction and parenting. The bizarre crests, spikes, and bumps that adorn the heads of many hadrosaurs (maiasaurs have a crest just over the eyes) have been interpreted as secondary sexual characteristics. That is, these features helped hadrosaurs choose and recognize mates and thereby promoted bonding and successful breeding. According to James Hopson, of the University of Chicago, and Peter Dodson, of the University of Pennsylvania, these physical flourishes were best developed in sexually mature hadrosaurs, and in some species, one sex had bigger, more flamboyant crests and spikes than the other.

The social repertoire of hadrosaurs may well have included vocalization. In hollow-crested hadrosaurs, or lambeosaurs, the crest is actually a greatly modified nasal cavity and probably functioned as a resonating chamber, amplifying sounds generated in the lambeosaur's throat. Hadrosaurs without such crests had similar but smaller resonating chambers in their beaks. Adult hadrosaurs could have used vocalizations to threaten interlopers around the nest, to intimidate enemies, or just to bluff their way out of a confrontation. Parents may well have communicated vocally with their offspring, much as a horse softly nickers to a newborn foal or whinnies to sound alarm. Low-frequency sounds resonating through the crests of lambeosaurs could have carried long distances. They are also hard to pinpoint, an advantage if an animal is signaling under threat of predation.

While our picture of hadrosaur social life is still incomplete, the Willow Creek Anticline has yielded yet another remarkable clue to dinosaur behavior. In 1981, an enormous bone bed containing the remains of at least 10,000 individual maiasaurs came to light. Members of a huge herd, they were apparently killed simultaneously in a great volcanic explosion and were entombed in ashes. Because they all died at the "instant" of the catastrophe, their size distribution represents the standing age distribution of the living herd. Most of the individuals were from twelve to twenty-five feet in length, something like the maiasaur version of the teenage years and older. Young maiasaurs are missing. We do know, however, that the juveniles were somewhere in the vicinity, because of the many nesting grounds found in nearby fossil beds along the Willow Creek Anticline. Perhaps these vulnerable young stayed with their mothers in small family groups after leaving the nests, serving a sort of apprenticeship before becoming herd members. Vast herds of maiasaurs must have ranged across the upper coastal plain. Most likely they foraged for shrubby foliage in times of plenty and perhaps seasonally migrated north (see "Long-distance Dinosaurs," *Natural History,* June 1989).

The nesting grounds, eggs, and embryos are keys not only to dinosaur biology but also to dinosaur life style. Although we often analogize, much of the satisfaction of studying the social behavior of dinosaurs comes from understanding these animals in their own right, not as overgrown lizards or crocodilians or big, hairless mammals. The Willow Creek Anticline, and more recently discovered, just as spectacular fossil sites that we are currently excavating, are open windows, affording us a good look at how these animals lived in a world much different from, but perhaps as various as, our own. □

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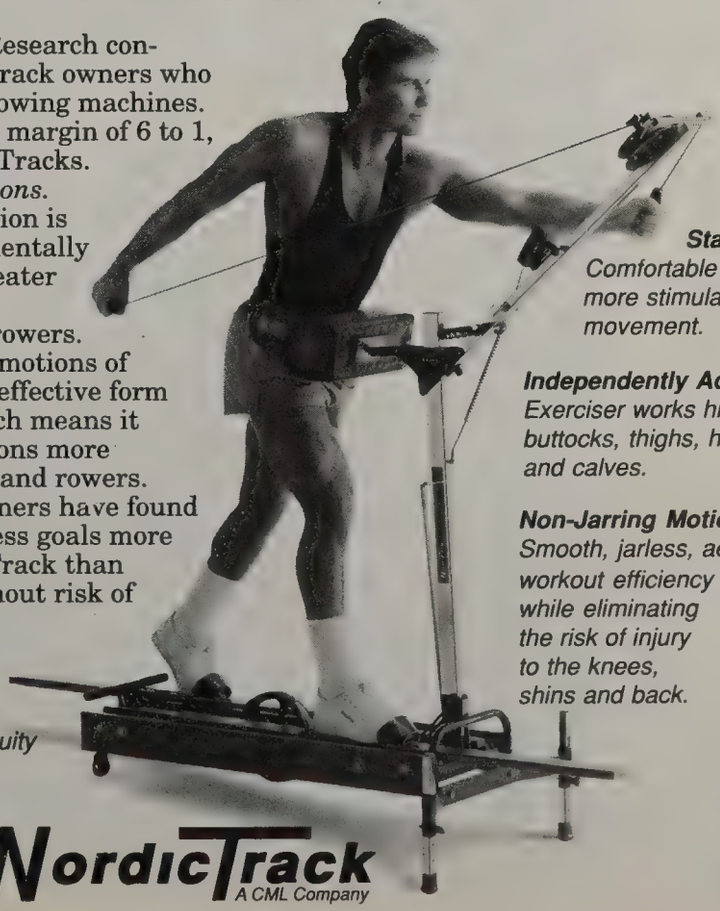

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A Bleak and Forbidding Landscape

by O. J. Reichman

The Great Basin is not one of those places that spontaneously inspires awe, like the Rocky Mountains, deep deciduous forests, or the incised canyonlands of the Southwest. At first glance it appears drab, composed of gray bushes and pink and tan rocks. The area seems monotonous and boring, with animals that only come alive at night and plants that save their beauty for more important times and audiences. This is, as the author notes, a region with "more mountain ranges than towns," a blank spot on the vacation map, where visitors roll up their windows, turn on the air conditioner, and rush through as quickly and painlessly as possible.

Author Stephen Trimble asks readers and prospective visitors to be patient with the Great Basin, to stop and peer into it, rather than beyond it. Its immensity is initially as forbidding to modern travelers as it must have been to the first European visitors, who had never seen such expanses. But Trimble wants the reader to go one-on-one with the Great Basin, as he himself obviously has on many occasions.

THE SAGEBRUSH OCEAN: A NATURAL HISTORY OF THE GREAT BASIN, by Stephen Trimble. *University of Nevada Press, $34.95; 262 pp., illus.*

If we oblige the author, we are virtually guaranteed a unique experience. As with most regions, "the" Great Basin is difficult to pin down. There is the one big basin, an area in which all the rivers flow inward with no outlet to the sea. This hydrographic region is the most explicitly defined Great Basin, and it stretches from Salt Lake City to Reno, and from west of Phoenix to north of Boise. There is also a physiographic Great Basin, defined by characteristic geologic formations. This provides a somewhat sloppier definition, as landforms are continuous and informed judgments must be employed to set boundaries. More subjective still is the biogeographic circumscription that incorporates the distributions of key plants and animals into the decision of what is and is not the Great Basin. Each of these characterizations yields specific borders, which, when overlain on each other, produce a central core region with edges that are more transitions than discrete boundaries. Nature resists neatness and does not respect political boundaries, so in fact there are an infinite number of Great Basins.

Within the core area, "in the rain shadow of the Sierra; west of the Wasatch Range of the Rocky Mountains; south of

Photographs by Stephen Trimble

The bleached remains of a bristlecone pine

the Snake River Plain; and north of the creosote bushes and Joshua trees of the Mojave Desert," exist unique, exquisite regions. Certainly the most characteristic geomorphic trait of the Great Basin is its basin and range topography. Conspicuous north/south ridges and depressions produce a "rhythmic chant of basin, range, basin, range" that is mesmerizing. They serve as a subliminal compass, a magnet to the senses, constantly revealing north and south, east and west.

In addition, these ripples in the landscape provide islands of habitat: lowlands separated by imposing mountains; mountaintops isolated by hot, dry valleys. The biogeographic consequences of this pattern are reflected in the insular distributions of residents, some of which exist in refuges of past climates. When glaciers last plowed into the middle latitudes of North America, the climate in the Great Basin moderated, and cooler, more moist habitats spread between the ranges. As these habitats receded up the mountains in response to departing glaciers, previously widespread habitat shrank. Many of these areas persist today with distinctive, self-sufficient communities.

As with oceanic islands, the Great Basin habitat islands are subject to periodic invasion from source areas. The Great Basin is very young in geologic terms and has not had time to evolve its own endemic flora and fauna. Thus, it has acted as a sink for invading species from its relatively old and biotically rich neighbors, the Rockies and the Sierra Nevada. Unexpectedly, the invasion of plants and animals has not been equal from the east and west. Rather, the Great Basin has accepted many immigrants from the Rockies while poaching only few from the Sierras. The author suggests that the ecological transition from the moist, cool Sierras into their low, barren rain shadow is more severe than the equivalent transition to the west from the Rockies. Here, on

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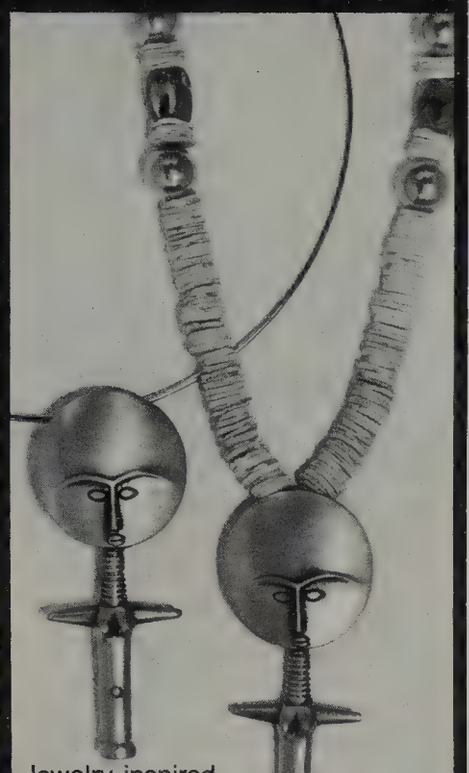

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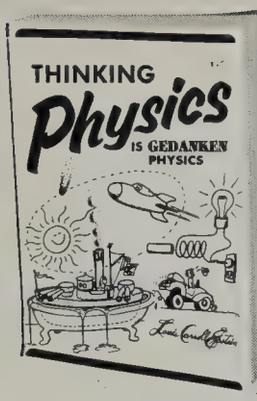

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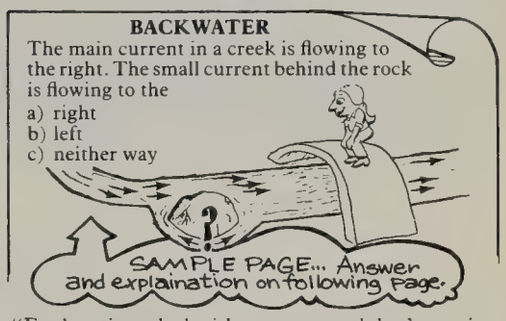
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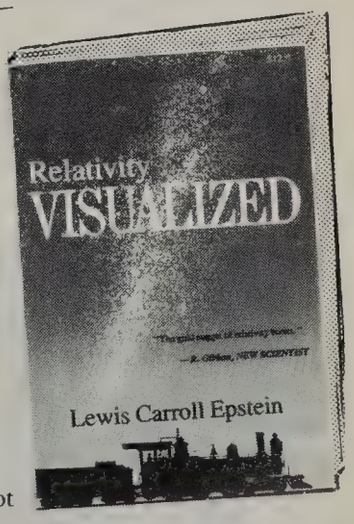

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The salt-encrusted landscape of the Bonneville Salt Flats

the western slope, the segue is more gradual, allowing incremental invasions rather than requiring great leaps of adaptation.

Characteristic habitats envelop large regions of the Great Basin. Huge expanses of greasewood, shad scale, and especially sagebrush (not, we are warned, to be confused with sage bush, which is tasty rather than acrid when shred into the evening stew) permeate the basins, and conifer forests reign over mountain ranges. More fetching, however, are the distinctive habitat islands that dot the entire altitudinal and geographic range of the Great Basin. Playa seres are bleak and barren until a sudden downpour turns them into an ephemeral miasma of muck and life. Equally barren are perennial saline or alkaline lakes that harbor a few weird residents adapted to these physiological deserts. And there is the "paradox of the dunes," a circumstance in which a landform thought to be characteristic of sterile deserts hosts one of the most diverse communities of creatures in the basin.

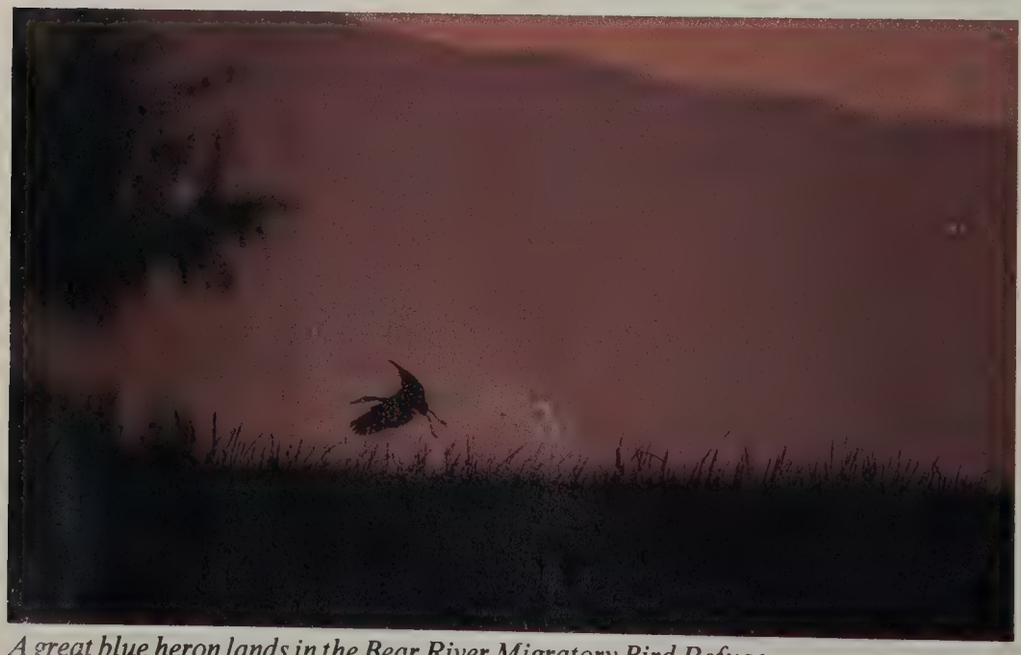
Within each habitat there occur unique life forms that perpetually inspire wonder. Bristlecone pines, the Methuselah trees, live at least three to four thousand years. That in itself is an awesome feat in a world where the difference between the quick and the dead may be a few millimeters of rain. But these aged conifers live in some of the most demanding habitats on earth. In summer the soils of their mountaintop redoubts are parched and the sun is intense, while in winter plentiful moisture is frozen solid and even less available than in the summer. Furthermore, these trees hang on by a thread, literally, retaining only a thin bead of nutrient-bearing tissue to communicate between their roots and their sparse vegetation.

The distinct pressures of the Great Basin have also been foisted on the anim that reside there. For example, the chis toothed kangaroo rat cohabits broad gions with saltbush, a severe little shr that packs its outer leaf tissues with sa For most desert animals, desiccation e gendered by the consumption of salt-lac leaves would preclude the inclusion of t shrub in the diet. This particular kangar rat, however, possesses broad, flat incis across which it pulls saltbush leaves, str ping them of their impregnated epid mis. The remainder of the leaf serv nicely in the rodent's diet.

The relative simplicity (emphasis relative) and distinctiveness of the Gre Basin makes it an attractive laboratory f scientists investigating important geolog and biological theories. For examp Trimble writes in great detail througho the book on the biogeographic mysteri of the region. In a most general manne he interprets what early investigato imagined to be the biogeographic pro esses as "climate + history = vegetatio vegetation + history = animals." Whi this may be a robust generalization, it do not adequately convey the actual pro esses of dispersal and adaptation. Accor ingly, the author delves deeper into a fe specific scenarios that are generally a cepted as parsimonious explanations f current patterns.

A good example emerges from an exp sition of the distribution of pines. The a thor notes that the driving forces behin existing patterns are threefold. First, sp cific emigration routes determine whe expanding pine populations can go. Subs quently, seed-eating birds facilitate th process by harvesting seeds from trees an storing them in distant, undergroun caches for future use. Finally, seeds tha escape recovery by birds may germinat and grow, only to be limited in distributio by decreasing summer moisture to th west. This and other revelations give or the sense that, like gold in a miner's pa plants and animals are continuously slosh ing around in the Great Basin, sometime spilling out into adjacent areas but mor often settling into the basin core.

The most distressing accounts in th book deal with aspects of land manage ment in the Great Basin. This is a regio heir to all the classical conflicts betwee private lands and the private use of publi lands. Embedded in the multiple-use pol cies of federal agencies are opportunitie to permanently scar the landscape or t send it off on a new biological trajector Like all places on earth, the Great Basin i always changing in what we might imag ine to be a natural manner. This gradua imperceptible change is being replaced b



A great blue heron lands in the Bear River Migratory Bird Refuge

perceptible, measurable degradation. The roots of the basin's vulnerability lie in its simplicity. Little events, even footprints and tire tracks, encroach on this fragile environment, and its slow weathering and low productivity make healing the scars a century-long process.

More pernicious still is the forced management of certain habitats that are viewed as unproductive. Of course, "productive" is used here with regard to a contemporary capitalist economy, not the inherent balance of trade that has evolved over the millennia between the basin's denizens. Trimble details one such metamorphosis in which a piñon-juniper habitat is managed into a "transformed woodland." A cascade of events, weaving "the political and practical with the desirable," has yielded an irreversible domain where multiple use has become multiple abuse. In one macabre instance the capacity for a habitat to sustain livestock was determined by filling it with cows and letting the number that survived over winter indicate its carrying capacity.

Trimble often encourages the reader to "glory in the detail" of the Great Basin, and this is a pleasing invitation. In fact, it is in the details that the true nature of the region emerges. But it is also in the relating of details that the book sometimes becomes fractured, snipping concepts into threads that must be knotted back together by the reader. For example, bristlecone pine is discussed in more than twenty places in the text in a manner that eventually links many aspects of its biology but that also tends to dilute the impression of this magnificent plant.

It is not clear which audience will benefit most from *The Sagebrush Ocean.* While it is an introduction to the Great Basin, a general knowledge of biology and geology jargon by readers would be helpful, and some may find the detailed references to specific mountain ranges and to epochs and eras of the past (which may be the most learned and forgotten items in any young scientist's liturgy) daunting. But for map freaks and detail junkies, Trimble's route through the Great Basin can be stimulating.

Not all points are presented in great detail, and as must be the case, some receive little attention. One environmental issue many readers will associate with the Great Basin, the controversy over exploding wild horse populations, receives little notice. There is a paucity of information about archeological evidence in the Great Basin, but this may reflect a true absence of information rather than the selectivity of the author. On a lighter note, the source of names for some mountain ranges are obvious (the Carson Range, named after the enigmatic explorer Kit Carson), but others are peculiar and provoke curiosity (the Wah Wahs, the Paw Raws, and the Charles Sheldon Antelope Range).

This is an eye-opening account of an unknown and unappreciated area in North America. The text is embellished with exquisite photographs (taken by the author) that make the apparently mundane into the obviously intriguing. In the book we learn about open spaces so vast that the only echoes would be off the stars, and mountains like Rose Peak where one could wave an arm at sunset and see the shadow disappear over the limb of the earth. This inward-turning basin, where, as the author reveals, you can feel alone but not lonesome, finally gets its due in *The Sagebrush Ocean.*

O. J. Reichman is an associate professor of biology at Kansas State University. Reichman, whose research deals with the impact of underground animals on plants, is the author of Konza: A Tallgrass Natural History *(University Press of Kansas).*

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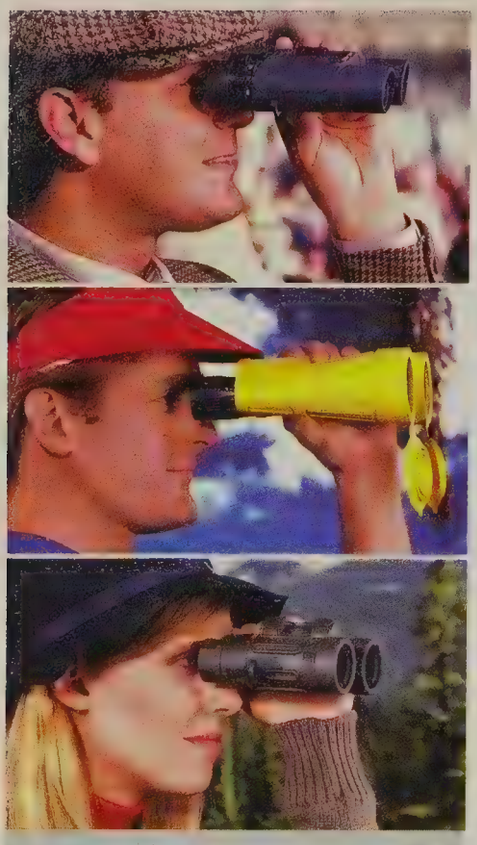

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Eight out of Ten

by Thomas D. Nicholson

Winter nights are noted for the brightest stars. Orion and its neighboring constellations, Canis Major, Canis Minor, Gemini, Auriga, and Taurus, bring six of the ten brightest stars visible from the northern midlatitudes into view: Sirius, Capella, Rigel, Procyon, Betelgeuse, and Aldebaran. This month, these brilliant stars of the winter sky rise in the east in the evening and set in the west near dawn.

December's evening sky has an added bonus in the west, where the bright stars of the Great Summer Triangle are still visible. Not a constellation, the Triangle is formed by the brightest stars of three constellations. Altair, the southernmost star in the Triangle, belongs to Aquila; Vega, the brightest of the three stars, is in Lyra; and Deneb is at the tail of Cygnus, although it is better known as the bright star at the top of the Northern Cross. Deneb is not among the ten brightest northern stars (it is fifteenth), but Vega and Altair are, bringing the total up to eight.

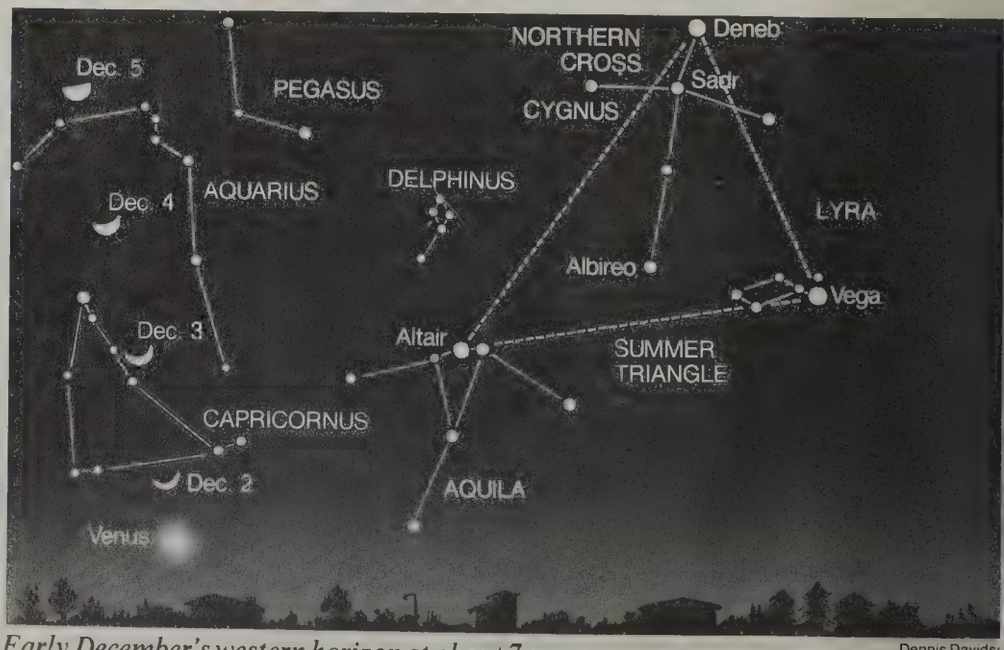
All of our brightest winter stars are up by 9:00 P.M. in December. The stars of the Great Summer Triangle are visible in the west from dusk until about 9:30 P.M. at the beginning of the month and 7:30 P.M. at the end. A month later, in January, t winter constellations are higher and st striking, but the Triangle and its brig stars are visible only briefly, after dusk.

We still see those bright summer sta so well because December brings the lon est nights and earliest sunsets of the yea January is a close second, but the nigh shorten slowly after the winter solstice December 21.

The appearance of the Summer Tria gle stars is better in some ways in Decer ber than in the summer. The Norther Cross is far more convincing now whe seen standing upright above the nort western horizon with bright Deneb mar ing its head, than when we see it on its sic in the east early in the summer. And w don't have to crane our necks to see overhead, as in the late summer.

Events in the calendar below are give in local time unless otherwise indicated.

December 1: Now three days past ne the young crescent moon is in conjunctio with Saturn this morning. When we see tonight, brilliant Venus is next to it. Venu is a spectacularly brilliant evening "star in the southwest. In a telescope, it can b



Early December's western horizon at about 7 P.M.

Dennis Davids

een as a crescent that grows larger and hen thinner as the month progresses. Saturn is still above the horizon but harder to ee below and to the right of the moon.

December 2: The moon covers Venus an occultation) early in the day over nuch of Asia and appears above the planet in our sky tonight.

December 3–4: The bright Summer Triangle stars are well above the horizon o the moon's right as the sky grows dark.

December 5–6: First-quarter moon is at 3:26 P.M., EST, on the 5th, just between Aquarius and Pisces. On the 5th, the noon moves below Markab and Scheat, he right side of Pegasus' great square, nd is at the bottom of a loop of dim stars orming Pisces' Southern Fish on the 6th.

December 7: The 21st is the shortest lay of the year, but our earliest sunset is oday. Daylight lingers noticeably longer n a week or so.

December 9: Aries' brightest stars, Hanal and Sheratan, are to the moon's right.

December 10–12: The gibbous moon nters Taurus and reaches perigee nearest the earth) as it approaches the Pleiades cluster on its way toward bright Jupiter. Full moon occurs at 11:30 A.M., EST, on the 12th, and dominates the sky, crossing high above between dusk and dawn.

December 13: Joining Jupiter in Gemni, the moon is in conjunction with the planet at 3:00 P.M., EST, and is above and o its left when we see them tonight.

December 14: Moonlight will spoil the Geminid meteor shower's maximum early his morning. Gemini's twins, Pollux and Castor, point down to the gibbous moon as hey rise after dark. Venus is at its greatest brilliance in the night sky, dominating the outhwestern sky at dusk.

December 16–17: The moon rises late, after 9:00 P.M., and moves up in the sky with Leo's Regulus, above the star on the 6th, below it on the 17th.

December 19: Last-quarter moon, at 6:54 P.M., EST, rises after midnight in Virgo. The bright star behind the moon is Spica, while Regulus is above the moon.

December 21: The sun is at the winter solstice, its most southerly position in our sky. Winter in the Northern Hemisphere begins at 4:22 P.M., EST.

December 22: The Ursid meteor shower is not a major one, with only about fifteen meteors visible per hour, but the waning crescent moon this morning or tomorrow should not hinder viewing. The moon is at apogee (farthest from the earth).

December 23: Mercury reaches its greatest distance to the sun's left during a relatively poor evening elongation, setting some one and a half hours after sunset.

December 25–26: Mars has been an obscure morning star in Libra most of the month. Now in Scorpius with the thin, waning crescent moon, the dim red planet can be seen above and to the left of the moon on the 25th, and above and to its right on the 26th. Don't confuse Mars with brighter Antares, which is very close and to the moon's right before dawn on the 26th.

December 27: Brilliant Jupiter, at opposition from the sun, becomes an evening star, visible all night as it moves from the eastern to the western horizon. Venus begins retrograde motion (westerly) through the stars, signaling its rapid approach to conjunction between the earth and the sun next month. New moon occurs at 10:20 P.M., EST.

December 30: Early today, Venus and the moon are in conjunction. During dusk, the thin crescent moon will be above and to the left of Venus. Mercury's retrograde motion begins as its poor evening display draws to a close.

December 31: The thicker crescent moon is at the border between Capricornus and Pisces again, about where it was on the 4th.

Editor's Note: The Sky Map in the October issue shows the evening stars and constellations for this month and gives the dates and times for use.

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At the American Museum

Crossroads of Continents

Since Asians first migrated to America more than 16,000 years ago, there have been continual cultural contacts and exchanges across the Bering Strait. The first major ethnographic exhibition to be jointly developed by Soviet and North American institutions, *Crossroads of Continents: Cultures of Siberia and Alaska* opens in Gallery 3 on Friday, December 15. The exhibition brings together for the first time the art and history of the peoples of northeastern Siberia, Alaska, and British Columbia. Some 500 artifacts, including clothing, carvings, beadwork, masks, musical instruments, kayaks, and weapons, reflect the mythology, spiritual traditions, ecological adaptations, technological development, and trade of these northern peoples.

The American Museum of Natural History houses one of the world's most extensive collections of Siberian artifacts, gathered by the Jesup North Pacific Expedition of 1897–1903. The Museum of Anthropology and Ethnography in Leningrad, the world's leading repository of Alaskan artifacts, has contributed objects collected during the eighteenth and nineteenth centuries, when Alaska belonged to Russia. Other objects on display are on loan from the Smithsonian Institution and other museums in the United States, the Soviet Union, and Canada.

Crossroads of Continents will remain in Gallery 3 through March 25, 1990.

Digging Dinosaurs

In 1978 paleontologist John R. Horner, excavating in Montana, uncovered the first nestful of baby dinosaurs ever discovered. During the next five years, he and his colleagues found hundreds of dinosaur eggs at the site they called Egg Mountain. These fossils led Horner to formulate the revolutionary theory that some dinosaurs were nurturing creatures that actively cared for their young. (See "Dinosaur Eggs: The Inside Story," page 60.) Horner will discuss his findings on Thursday, December 14, at 7:30 P.M. in the Main Auditorium. Tickets are $7 for members and $12 for nonmembers. For information, call (212) 769-5606.

Kwanzaa

Kwanzaa, a Swahili word meaning "the first fruits of the harvest," is a week-long holiday celebrating the richness and diversity of African cultures and the African-American diaspora. Now in its twenty-third year, *Kwanzaa* runs from December 26 through January 1, with each of the seven days dedicated to one of the *nguzo saba,* or "seven principles": *umoja* (unity), *kujichagulia* (self-determination), *ujima* (collective work and responsibility), *ujamma* (economic cooperation), *nia* (purpose), *kuumba* (creativity), and *imani* (faith). The Museum's Kwanzaa celebration, cosponsored by the Education Department and the New York Urban Coalition, will be held Wednesday and Thursday, December 27 and 28, and will feature music, dance, folktales, games, and cloth design. Free tickets will be available on a limited basis. For information, call (212) 769-5315.

Native American Celebration

The Leonhardt People Center celebrates Native American culture with free weekend programs in December. Social dances and dramatic tales of the Blackfoot and Narraganset will be featured along with other aspects of Native American culture, such as growing up Tlingit love stories (dramatized by Vira and Hortensia Colorado), beadwork and quilt making of the Plains, the art of decorating with porcupine quills, and herbal traditions. The Thunderbird Dancers will perform in the Kaufmann Theater at 3:00 P.M. on Saturday, December 16. The People Center will be closed the weekends of December 23–24 and 30–31. For a full schedule of events, call (212) 769-5315.

Origami Holiday Tree

The seventeenth annual display of the *Origami Holiday Tree* runs from Monday, November 20, through the holiday season. Because the Roosevelt Rotunda (the tree's traditional location) is closed for renovations, this year's tree is in the Roosevelt Memorial Hall near the information desk. In celebration of the Museum's 120th anniversary, many paper dinosaurs adorn the tree, along with ornaments folded in the shapes of mammals, insects, comets, and other creatures and natural objects. To reflect its new location near the Hall of Ocean Life, the tree also sports models of such sea creatures as barracuda, jellyfish, whales, and manta rays. Volunteers are on hand to show visitors how to fold their own origami ornaments.

These events take place at the American Museum of Natural History, located on Central Park West at 79th Street in New York City. For more information about the Museum, call (212) 769-5100.

Smithsonian Institution; Collection of the National Museum of Natural History

Bering Sea Eskimo mask, collected in Alaska in the late nineteenth century

Adapted from a U.S. $1 bill.

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This competition is part of the magazine's 90th birthday celebration. So we have scraped together $10,000 in cash prizes. Two eminent photographic firms, Kodak and Nikon, have joined the party by cosponsoring the contest. Winners will be published in the June 1990 issue of NATURAL HISTORY and exhibited at the American Museum of Natural History.

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A number of Honorable Mentions ($250) will also be awarded.

RULES

1. All entries *must* be unmounted prints, preferably in double-sized or jumbo version, but no larger than 5 by 7 inches. Do not send original slides or film. Put the category of entry and your name and address on the back of *each* print.

2. You may submit up to six entries (a sequence is considered a single entry). The pictures must have been taken by you and not have been previously published.

3. The competition is open to everyone except employees of the American Museum of Natural History, Nikon, and Kodak.

4. If your entry becomes a winner, you agree to lend us the original film and to let Natural History publish, promote, and exhibit the photographs.

5. Fill out and enclose an official entry form (or a facsimile).

6. If you would like the prints returned, you must include a self-addressed, stamped envelope.

7. Entries must be postmarked no later than March 1, 1990.

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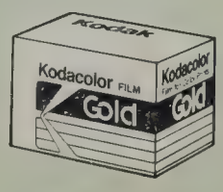

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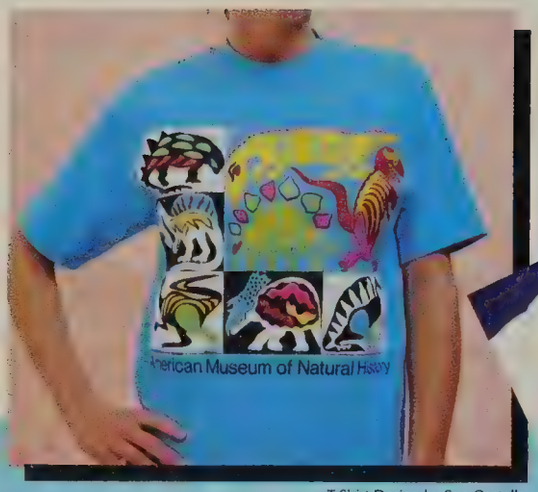

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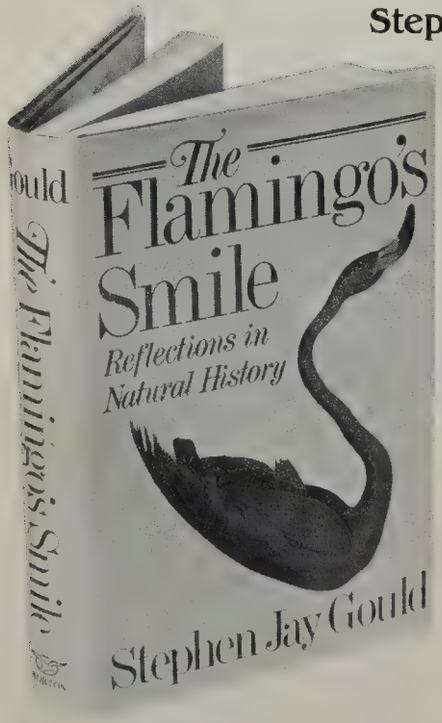
Stephen Jay Gould



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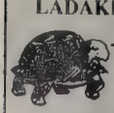

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Peruvian Provisions

Peru's traditional cuisine remains obscure—but the country's isolation may be why

by Raymond Sokolov

In the plush suburb of Miraflores, a sort of Peruvian Malibu, I had dinner with Carlos Raffo. He is a man of refinement, a man who speaks nostalgically of the Ligurian coast of Italy and his British golf club. When I met him in the spring of this year, he had just returned from a posting as Peru's ambassador to England. Now he is minister of industry, integration (which means furthering the cause of cooperation between the Andean nations), and tourism. On the minister's shelves are complete sets of Aristotle and Plato in Spanish. This fanatical gourmet, who orders rare titles in gastronomy from Cooks Books in Rottingdean, England, poured French wine and served me the purest Andean meal it is possible to imagine: corn on the cob, with salt.

But this was not the eccentric part of my dinner with the minister of tourism of Peru. What could be more appropriate to serve a visitor on a gastronomic mission to Peru than this world-changing local grain in its most elemental form? Nor was I in a position as a North American used to corn, multifariously, since infancy, to feel blasé about Raffo's offer. The corn of the Andes is not our corn. The kernels are much bigger, the taste and texture different. Peruvians call it *choclo,* and it is just one of a hundred fundamental things that make Peruvian food a world apart. So I accepted this Spartan meal as a tribute from one discerning eater to another. Remarkable but not strange. No, what was odd was the pistol stuck in the minister's belt, visible against his trencherman's belly.

There were also armed men at the door and a hoarse gunsel of a driver for the minister's Volvo. You see a lot of guns in Lima these days, because of the actions of the Sendero Luminoso (Shining Path) Maoist guerrillas and other forms of violence and crime provoked by economic chaos. The minister, ever jovial and not one to admit that his tourism portfolio is a bad joke in times when no traveler to the interior of Peru is safe, is an obvious target for assassination. It occurred to me that to dine with him on *choclo* was to take a seat in a potential cross fire. Even to stay in his house finishing my wine after he left to meet his wife at the airport was to prolong the risk. The airport itself is an emblem of the precariousness of life. Named for Jorge Chávez, a Peruvian pilot who made the first flight from Switzerland to Italy in a small Bleriot plane in 1910—a flight that ended in a fatal crash—the airport is surrounded by the hovels of Lima's dreary port of Callao.

A taxi ride away, Lima perches on the foggy cliffs of Peru's Pacific coast, where Francisco Pizarro founded it as a stronghold against Inca rebellion and unrest on January 18, 1535. The Andes stand off a short distance, filled with treasure, menace, and a biological wealth that changed the rest of the world more than all the gold raped from the Incas and taken from the bowels of Bolivia to the east. Through Lima, once glittering outpost of the Spanish empire, the potato escaped from the frigid *altiplano* and transformed itself into shepherd's pie, *omelette à la Parmentier, pommes Anna,* the plum dumplings of Szathmar, *Kartoffelnsalat,* French fries, potato chips.

We could probably go on naming potato dishes invented outside Peru for page after page without even consulting a reference book. But I doubt that most people can come up with a typically Peruvian potato dish off the top of their heads. Peru is also the ancestral home of the tomato and the chili (capsicum) pepper, but in the world at large, Mexico gets the credit for these plants, having cultivated the versions of them that entered other cuisines after Columbus.

No doubt, Mexican tomatoes do deserve their world fame and not the little green wild ones that grow in Peruvian river valleys and which started the world's love affair with tomatoes. No doubt, Central American corn deserved its role as the hybrid of preference almost everywhere since it was the oldest. But how can we explain the continued insularity of Peruvian hot peppers, the aggressively delicious *mirasol* and the big red *rocoto* which combines the suavity and juiciness of the red bell pepper with the heat of Mexico's finest? How, indeed, can we explain the continued isolation and obscurity of Peru's traditional dishes, which make up the last great cuisine undiscovered by a world gone mad for new tastes?

To a degree, the nature of the food itself explains this. Roast or stewed guinea pig has no future in the non-Andean world. Even in Lima, this primordial source of protein in the aboriginal cooking of the country is not normally available. But in the countryside, poor Indians still raise guinea pigs (*cui*) as a major meat source just as their ancestors did before the conquest brought in the domesticated meat animals of Europe. In shacks all over rural Peru, miniflocks of *cuyes* scamper on the floors, waxing fat at the feet of, and sharing the same roof with, people who will eventually eat them. The other nonexportable Peruvian standby is *anticuchos,* a vigorously spiced preparation of marinated cubed beef heart barbecued on skewers. The name sounds as though it is a Spanish word related to antipasto and cuchifritos, an appetizer/snack. But Elisabeth Lambert Ortiz reminds us that *anticuchos* is an indigenous Quechua term meaning "a dish from the Andes cooked on sticks," and that it was probably first made with llama hearts in the days before beef. I can attest that the modern recipe, even when done with non-Andean chilies, is very delicious, but I doubt that it will win the hearts, so to speak, of offal-squeamish non-Andean cooks.

Various other Andean foods do not look like good bets for the wide world because the niche they fill in Peru and Bolivia is already satisfactorily occupied elsewhere. We in the first world already have access to enough potato varieties not to feel more

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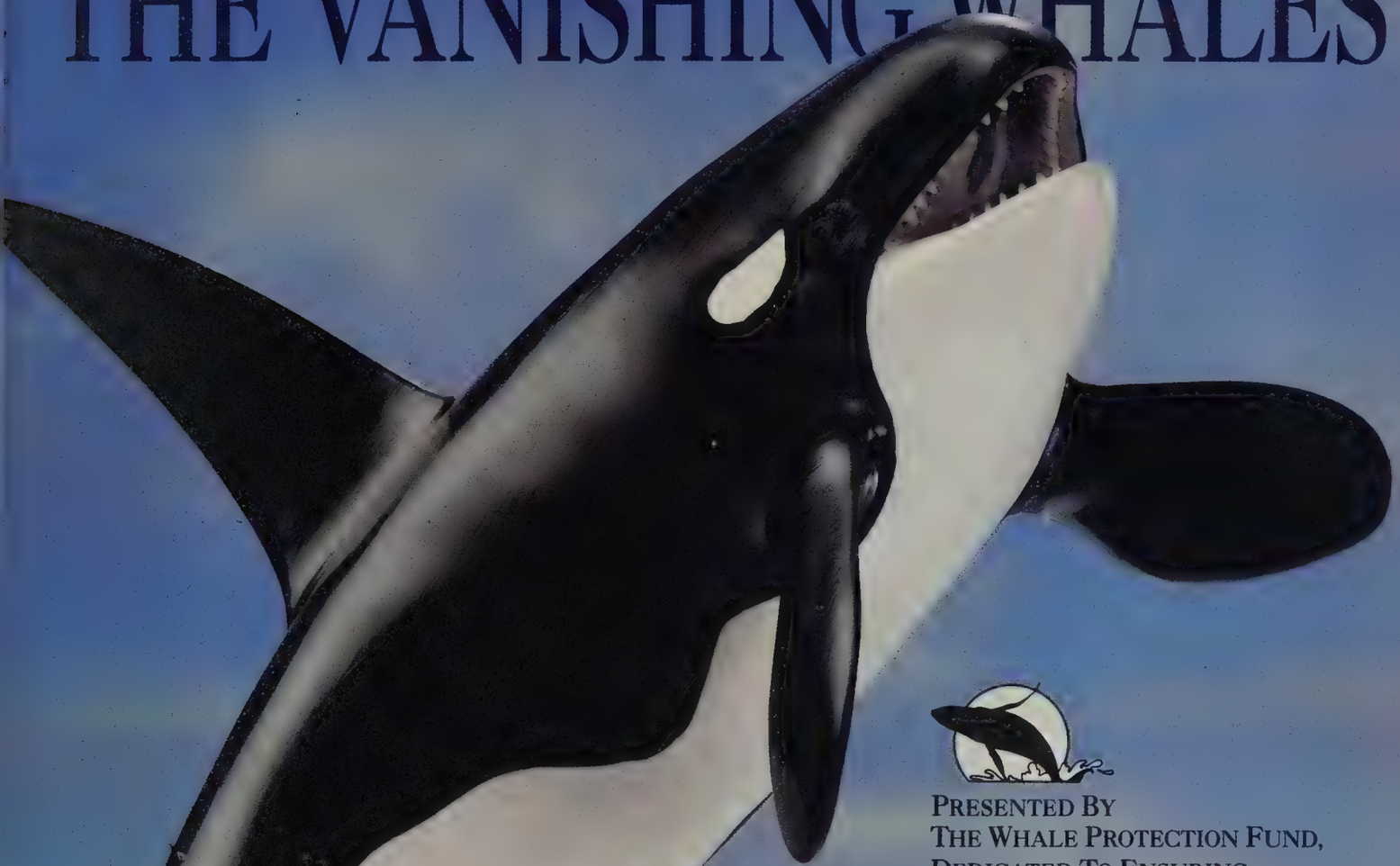

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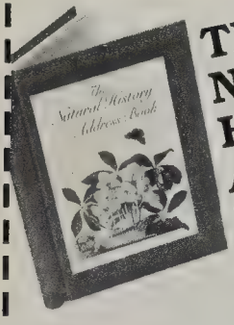

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than titillated by the unexploited cornucopia of Andean types in all their many colors and shapes. Perhaps the *papa amarilla,* the yellow potato, with its lusciously waxy texture, which does not turn mushy, glutinous, or starchy when cooked, has a future, but the demand would have to be carefully nurtured. Other Andean tubers (except the sweet potato) stand no chance at all, not even the thumb-shaped, iridescent, yellow-green-fleshed *ulluco.*

Peru's relatively greater isolation from Spain and North America—compared with the relatively greater accessibility of Mexico and the Caribbean Islands—put all its foods, except the uniquely valuable potato and sweet potato, at a competitive disadvantage with similar foods from the more convenient parts of the Spanish empire. Thus Mexican maize became a plant of world significance, while large-kerneled *choclo* stayed at home. The same is true for Andean chilies in a world already growing the full panoply of Mexican varieties. But this neglect and isolation has allowed Peru to develop its Creole cuisine in peace since the sixteenth century. The quintessential isolation of the Indian population in the Andes, until the fateful migrations to Lima's shantytowns of the last few years, has preserved traditional agriculture and ingredients.

In the rough-and-ready dawn at Lima's central market, a woman known as *la reina de papas,* or "potato queen," reigns supreme over the capital's potato trade, and so it is within sophisticated Miraflorean's easy reach to buy the air-dried potatoes (*chuño*) of the cordillera and cook them in their walled mansions by the Pacific. Indeed, it is possible to buy *papas secas* in the New York metropolitan area, most specifically at Inca's Foods on Broadway in Passaic, New Jersey, where refugees from troubled Peru have taken to settling. Reportedly eighteen restaurants in Paterson and Passaic serve them such typical dishes as *chupe* (a potato-thickened shrimp stew) or *aji de gallina* (chicken in a sauce of milk, bread crumbs, and puréed red hot chilies, called *aji* in South America).

I went to one of these places, La Furia Chalaca, at 87 Broadway in Passaic, next door to Inca's Foods retail shop. The name means the madwoman of Callao, but it was a calm, friendly place with a fairly large number of typical dishes. It isn't really necessary to leave Manhattan to have this kind of experience. Falcon's Peruvian Restaurant (466 Amsterdam Avenue between 82d and 83d streets) is a well-appointed place only a short walk from the offices of this magazine in the American Museum of Natural History. It offers an excellent cod *seviche,* the raw fish/citr juice/chili/onion dish common to most Spanish America. There is *papa a huancaina,* cold boiled potato in a chee sauce; *carapulcra,* bits of pork and *pap secas;* fish *chupe;* tripe dishes that prob bly descend from recipes brought to Pe by black slaves from Africa; and for t gastronomic adventurer, *mazamor morada,* a viscous purple "jello" ma with dried purple corn.

In Lima, I went to some real trouble try the supposedly widespread, nonalc holic purple drink made from this san corn, called *chicha morada,* and event ally risked dysentery or God knows wh by downing a glass of it from a stre vendor stationed at the city's main squar the Plaza San Martin. He served h *chicha* in real glasses, rinsed in a comm nal bowl of water. I suffered no ill effect but I will confess that I was much happi at a spectacular lunch at a glamorous ne restaurant next to the Gold Museum. Th restaurant, El Pabellon de Caza (the hu pavilion), is decorated with big-game tr phies, has parrots, a jungle garden, French chef, and an ebullient man at th helm, Arturo Rubio. He is a dynamic en thusiast for the dishes of his country, fro the most traditional to the latest wrinkl which is a marriage of *seviche* and sashin called *tiradito* (little strip). Lima has re cently attracted a serious Japanese popu lation (it has had a big Chinese contingen for a long time and many Chinese restau rants called *chifas*). *Tiradito* consists o thin strips of raw fish very slightly cured i citrus and served without adornment, no even onion—just seasoned with chili. Ru bio offered me a *tiradito* of octopus an another of *lenguado,* a white-fleshed Pa cific fish that is conventionally translate as sole.

I was able to experience this extremel pure-tasting hybrid on its home groun two days later, at Rosita's, one of innumer able small, cheerful, extremely informa restaurants scattered throughout scruff Callao. It is in such inelegant surround ings that Limeño businessmen lunch seeking authenticity and inverse chic. No everyone goes in for this sort of thing, o course, and when my meeting with Minis ter Raffo was under discussion, he ex pressed the hope that I would not insist on going to Callao to *comer sucio* (eat filthy)

As far as I could tell, sanitation was wel maintained at Rosita's by the amiable pro prietress, Rosa de Yimura, and her hus band, who did card tricks and other con juring in the al fresco dining room, whil his wife and daughters prepared tempura *tiradito;* two kinds of octopus *seviche,* on in olive cream; *tacu-tacu,* a patty of ric

ınd baked beans with stewed goat; and a Chinese-Peruvian combination of *lengu-ıdo,* peaches, and scallions. Rosa de Yimura's cooking, half Oriental, half Pe-ıuvian, embodies the latest stage in a mil-ennium of genetic and culinary mixing ınd adaptation in Peru. To merge sashimi vith New World *seviche* (itself probably a Moorish contribution to Andalusian nenus), and to compound the creolizing ffect with an olive cream, is *nouvelle uisine* (really *nueva cocina*), but the ancy term isn't necessary in Callao, di-apidated melting pot on the foggy south-astern edge of the Pacific rim.

Raymond Sokolov is a writer whose spe-ial interests are the history and prepara-ion of food.

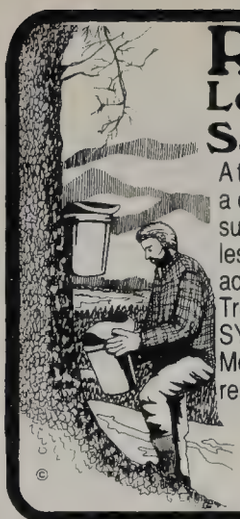
Anticuchos

(Barbecued beef heart adapted from Francisca Baylon's *Comidas Criollas Peruanas,* Field, Lima, 1959)

- 2 beef hearts
- Salt
- Pepper
- 2 heads garlic (approximately ½ pound), peeled and ground to a paste in a mortar, blender, or processor
- 2½ tablespoons ground cumin
- 2 tablespoons finely chopped fresh chilies
- Vinegar
- ¼ pound dried chilies (*mirasol* is traditional; substitute ordinary dried red chilies), seeded
- 2 tablespoons lard
- 1 tablespoon annatto (*achiote*) seeds
- Steamed corn

1. Wash and trim the hearts, removing all fat and sinew. Cut meat in one-inch cubes. Marinate overnight or longer in salt, pepper, garlic paste, cumin, chopped fresh chili, and vinegar to cover. Stir from time to time. Keep covered.
2. While the meat is marinating, soak the dried chilies in lightly salted water. The next day, drain the chilies, combine with ½ cup of the solid part of the heart marinade, and salt to taste. Separately, heat the lard and sauté the annatto seeds in it until they color the lard red. Add this mixture to the chili/marinade mixture and purée in a blender or processor. Add vinegar from the marinade to make a smooth sauce.
3. Drain the beef heart chunks and put them on skewers, six per skewer. Put over a hot grill, baste with sauce, and let cook. It is traditional to do the basting with thin strips of corn husk knotted together to make a brush. Serve with steamed corn.

Yield: 8 to 10 servings



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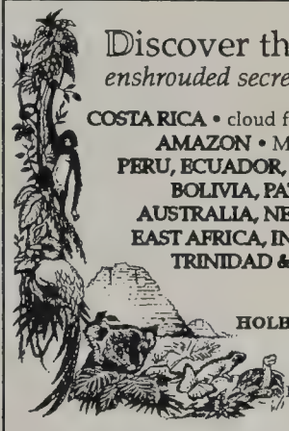

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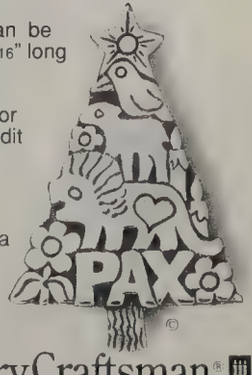

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From Here to Paternity

Photograph by Kennan Ward

In December, when northern elephant seals lumber onto land to mate, the beach becomes a battlefield as well as a breeding ground. Fierce combat determines the few top bulls—about 5 percent of the males—that will lord it over the harem and inseminate nearly all the females. The weaker males will be exiled to the edge of the rookery.

Now and again, a sidelined male may invade the harem, only to find, as here, that the dominant bull is not about to give up his monopoly without a fight. The defender rears up, raises his huge, fleshy proboscis—the distinguishing feature that gives the species its name—and bellows a warning. If the challenger stands firm, the chief bull charges, crushing everything in his path, including newborn pups.

The combatants smash their thick, calloused necks and shoulders together, and each tries to sink his canine teeth into his opponent's proboscis, which is engorged with blood and larger than usual during the December to mid-March mating season. Although gory, such battles rarely result in serious injury.

These two bulls fought for forty-five minutes on a beach in California, then plunged into the surf, which reddened with their blood. Several minutes later, they disappeared underwater. Eventually, one bull—whether it was the challenger or incumbent is not known—returned to the beach.—*O. W.*

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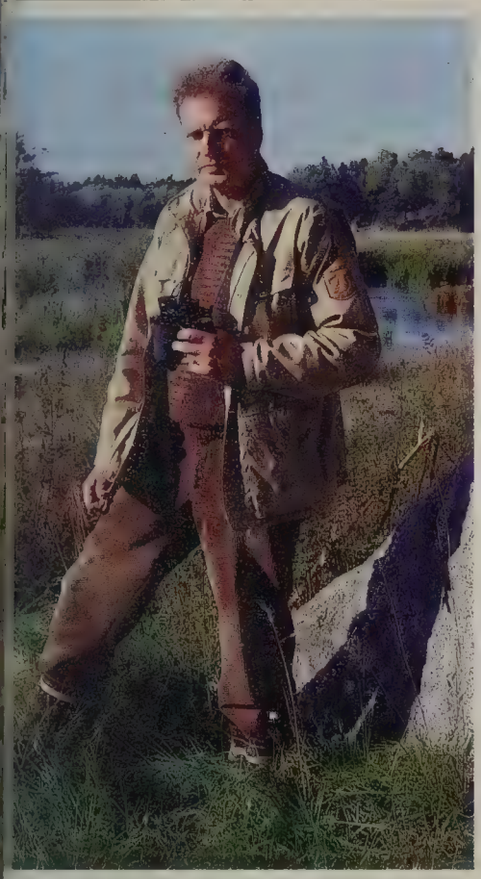
AUTHORS

Wayne Z. Trivelpiece (page 28) caught "polar fever" as a graduate student in 1976 while watching his first wild Adélie penguin come ashore on Admiralty Bay; **Susan G. Trivelpiece**'s turn came five years later. They met in 1980 while studying the toxic effects of oil on seabirds in Maine, but ever since, their collaborative research has focused on penguins in the cold Antarctic. Staff biologists at the Point Reyes Bird Observatory in Stinson Beach, California, the Trivelpieces spend about five months of every year in Antarctica, generally during the penguins' breeding season. Both are avid hikers and cross-country skiers, which is fortunate, since feet and skis are the only practical means of transporta tion at their antarctic field camp. Th technology they use to track the move ments of penguins can be considerabl more sophisticated, however, and in th future, they hope to learn much mor about the birds' foraging behavior an wintering range with time-depth record ers, radio transmitters, and satellit tracking. To keep warm perhaps, th Trivelpieces also have a research pro gram in the West Indies, where the study the magnificent frigate bird. Fo more on penguins, readers can turn t *Breeding Biology of the Adélie Penguin* by David G. Ainley, Robert E LeResche, and William J. L. Slade (Berkeley: University of California Press, 1983), and *Penguins: Past and Present, Here and There,* by George G Simpson (New Haven: Yale University Press, 1982).

Nature photographer **Kennan Ward** (page 84) spent years observing wildlife while working as a ranger in state and national parks all over the West Coast. In his free time, he often photographed the landscapes and the animals he had come to know. While working as a ranger at Año Nuevo State Reserve off the central California coast, he captured the picture of two battling elephant seal bulls for this month's "Natural Moment." Born and raised in Chicago, Ward studied environmental science at the University of California at Santa Cruz. Although nature photography is often arduous and frustrating, he says, "all the despair is forgotten when eye-to-eye contact is made with an animal in the wild or a window in the clouds opens up, highlighting a landscape." The picture of the elephant seals was shot with a 180-mm f2.8 lens on a Nikon F3.



Lennart Hansson (page 38) is a professor of population ecology at the Swedish University of Agricultural Sciences in Uppsala. As a student in the 1960s, he was interested in birds and plants, but his scientific fate was sealed when an academic supervisor asked him to undertake studies of rodents. Since then, Hansson has conducted field research on small rodents throughout Scandinavia. His current research is focused on the relation between population dynamics and behavior and physiology. When not chasing voles and mice across fields and through forests, Hansson enjoys quieter pursuits, especially reading about archeology and ethology. For a broad look at how the study of voles and mice fits into larger topics of ecology, behavior, and evolution, readers can turn to *The Ecology of Woodland Rodents*, edited by J. R. Flowerdew et al. (New York: Oxford University Press, Inc., 1985). Previous related articles in *Natural History* include "The Vole That Soared," May 1984, and "Hare Trigger," November 1981.

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Lydia T. Black (page 46) started researching the Russian period in Alaska as an outgrowth of her fieldwork among the Aleuts, which she began in 1975. Born in Kiev, USSR, she has been able to bring her own cultural background to bear on the subject. A professor of anthropology at the University of Alaska, Fairbanks, Black previously taught at Providence College in Rhode Island. For additional reading, she recommends *Russian America: The Great Alaskan Venture, 1741–1867,* by novelist Hector Chevigny (Portland: Binford & Mort Publishing, 1979); *The Wreck of the Sv. Nikolai: Two Narratives of the First Russian Expedition to the Oregon Country, 1808–1810,* introduced by Kenneth S. Owens and translated by Alton S. Donnelly (Portland: Oregon Historical Society, 1985); and *Builders of Alaska: The Russian Governors, 1818–1867,* by Richard A. Pierce (Kingston, Ontario: The Limestone Press, 1985). *Crossroads of Continents: Cultures of Siberia and Alaska,* by William W. Fitzhugh and Aron Crowell (Washington, D. C.: Smithsonian Institution, 1988), which includes chapters by Lydia T. Black, is the catalog for the exhibition currently at the American Museum.

John R. Horner (page 60) was born in the badlands of Montana, an ideal spot for a dinosaur-crazed, budding paleontologist. He was already involved in his future profession by the time he was eight. Dinosaur behavior, ecology, evolution, and more recently, physiology are Horner's consuming interests. He has broken new ground in all these areas, starting with his discovery of eggs and baby dinosaurs in 1978, when he was a research assistant in geology and a fossil preparator from Princeton, and continuing back home in Montana where he is now a curator at the Museum of the Rockies in Bozeman. Awarded a MacArthur Foundation Fellowship in 1986, Horner also has an honorary doctorate from the University of Montana. Often accompanied in the field by his son, Jason, he has studied dinosaurs of the late Cretaceous (from about 100 to 65 million years ago) all over the United States. **David B. Weishampel** combined an interest in paleontology, art, and biology from an early age. A fossil collector at seven and a student at the Cleveland Art Institute as a teen-ager, he received a doctorate from the University of Pe sylvania in 1981. He is currently an as tant professor in the Department of C Biology and Anatomy at the Johns H kins University School of Medicine. spends his summers in paleontologi pursuits, accompanied by his wife a two children, daughters who have be going "into the field" since they w about eight months old. Widely travel in Europe, Weishampel has be awarded fellowships and visiting prof sorships at universities in Poland a West Germany. He is senior editor o soon-to-be-published text, *The Di sauria,* the first reference work to compiled for professional pal biologists. Fascinated by the potent for vocalization in crested dinosau Weishampel has designed a long, d ble-bassoon-like instrument that p duces a deep bellow when he blows i it. He refers inquisitive readers to Dav Norman's *The Illustrated Encyclopea of Dinosaurs* (New York: Cresce Books, 1985) and the two-volume *Di saurs Past and Present,* edited by Sylv J. Czerkas and Everett C. Olson (L Angeles: Natural History Museum Los Angeles County, 1987).

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